E&PDE 2023

Engineering and Product Design Education

RESPONSIBLE INNOVATION FOR GLOBAL CO-HABITATION

Proceedings of the 25th International Conference on Engineering and Product Design Education

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E&PDE 23 Foreword

Responsible innovation for global co-habitation

The 25th International Conference on Engineering and Product Design Education (E&PDE) with the theme 'Responsible innovation for global co-habitation' was held at the ELISAVA, Barcelona School of Design and Engineering, UVIC-UCC on the 7th and 8th of September 2023.

The conference was hosted by the ELISAVA, Barcelona School of Design and Engineering, providing the principal locations and support for the conference. The conference was planned and arranged with the Design Education Special Interest Group (DESIG) of the Design Society, and the Institution of Engineering Designers (IED).

The E&PDE conference was initiated in 1999 in the United Kingdom and was consolidated as an international conference in 2004; alternately taking place in the UK and abroad. Its objective is to facilitate the bringing together of people from within education and industry who are interested in sharing expertise on the implementation and analysis of contemporary and developing methodologies in engineering and design education. It provides educators and researchers from product development, engineering and industrial design, together with industry and government representatives, with a platform for discussion on topical educational issues in design education and its future direction.

In 2019, the conference introduced visual papers where sketched images are essential in communicating the primary information, and text plays a supporting role. Visual papers aim to contribute new knowledge that have educational or research interest of the conference.

Conference theme

Design and Engineering have innovation at the core of their professional practice. Innovation might come from a technocentric drive, pushing technology to new limits without considering why or how that affects us as a society and a global community. The environmental crisis and the lack of improvement in areas such as pollution, biodiversity loss and climate change, demands that our efforts focus into new ways of co-habiting the spaces we share with each other, be it other cultures, other species, and the diverse eco-systems that support us. Therefore, we would like to dedicate the E&PDE 2023 conference to consider and expand the professional and pedagogic role that designers and engineers have in engaging on **Responsible Innovation for Global Co-habitation** that allows us to create futures that are inclusive, fair and pluralistic.

These proceedings are based on a call for papers that aims to:

- Share and improve design and engineering education, teaching and learning experiences
- Develop educational concepts and strategies to help students and graduates address current and future challenges
- Provide a platform to engage a wide and diverse community of participants and explore the various themes from different perspectives

These aims were addressed through the following conference tracks related to Engineering and Product Design Education:

- The effect that design and engineering have on global co-habitation
- Responsible innovation in design and engineering education
- Professional perspectives for design students in a pluralistic future
- International, multi-sectorial or multispecies collaborations
- Ethical, social and/or environmental issues in design and engineering, and their education
- Design and engineering as agents of regeneration and transformation

- Design and engineering from under-represented perspectives
- The potential of interdisciplinary activities to foster responsible innovation
- Sustainable development and working towards UN Sustainable Development Goals
- Established, alternative and emerging educational paradigms to equip engineers and designers for future challenges

During the conference over 150 participants from 24 countries delivered 4 workshops and 116 presentations. The initial conference call attracted 219 abstracts including 3 visual papers and 48 student contributions. After double blind peer review process of the full papers, 119 contributions were selected to be included in the 2023 E&PDE proceedings.

Keynote speakers were invited to discuss the topic of the conference. Clara Guasch Sastre who works in the strategic material and innovation development, spoke on her background and interest in systemic change through circularity and for more sustainable options. Clara was part of the core group for the Better Cotton Initiative in its initial and consolidation stages. At IKEA she also led the agenda for material and innovation development for textiles. In Elisava she takes part in the DTNM (Design Through New Materials) Master. She has lectured at ETP Textiles in Brussels, at DAE in Eindhoven, at the Volkenkunde Museum in Leiden and at MA-DE in Barcelona. She is a member of the council of the Urban Innovation Platform for Barcelona, BitHabitat, and of Hemp the Climate, an organization that supports the development of hemp as a climate positive industrial material re/source. As a consultant and advisor on strategic material and innovation development, Clara is helping companies shift towards more sustainable models. She wants to see positive change happen. To that end, she engages in different initiatives across various sectors. Whilst she keeps researching materials and innovations in connection to sustainability.

John Thackara was the second invited keynote speaker. John is a writer, advisor and event producer. For more than thirty years he has travelled the world in search of stories about the practical steps taken by communities to realise a sustainable future. John is the author of a widely-read blog and of How To Thrive In The Next Economy. His previous books (among twelve in total) were Wouldn't It be Great If... and In the Bubble: Designing In A Complex World (MIT Press). At the time of the conference, John is visiting professor at Tongji University with a focus on urban-rural reconnection; a senior fellow at the Royal College of Art; a Fellow of Musashino Art University in Japan; and visiting professor at Milan Polytechnic University.

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Thank you to all the members of the international academic review board who contributed to ensure the quality of the papers and presentations and of course all colleagues and students at the ELISAVA, Barcelona School of Design and Engineering, UVIC-UCC, that contributed to the planning and running of the conference.

Professor Isabel Ordóñez Pizarro – Industrial Design Engineer, PhD
Teacher and Researcher at ELISAVA, Barcelona School of Design and Engineering, UVIC-UCC
6th of September, 2023

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Our members enjoy a range of benefits, including mentoring and guidance to professional registration, exclusive access to our job board and newsletters to keep members up to date with relevant developments and events. We host regular events which offer our members the chance to network with other professionals and members receive the Institution's bi monthly journal – Engineering Designer.

We are committed to encouraging CPD for all our members and support ongoing training and skills development.

We offer a wide range of professional registrations: our own register for professional product designers includes the exclusive Chartered Technological Product Designer (CTPD) which is on a par with all other Chartered registrations and exists to provide professional recognition and standing to those suitably qualified and competent persons working in Product Design, with the sister grade of Registered Product Designer (RProdDes) for those not working at Chartered level.

We are licensed by the Engineering Council to assess candidates wishing to join the register of Professional Engineers and Technicians and we also accredit academic and training courses, for registration with either the Institution or with the Engineering Council. Those members who achieve the appropriate academic and competence standards receive Chartered Engineer, Incorporated Engineer or Engineering Technician status.

We are also a licensed body of the Society for the Environment and are able to register suitably qualified and competent members as Chartered Environmentalists (CEnv).

We welcome members from any organisation that has a design function and employs design engineers and we have many academic teaching staff in membership. To find out more about becoming a member of the IED and a professional registered designer go to http://www.ied.org.uk

The Design Society is an international non-governmental, non-profit making organisation whose members share a common interest in design. It strives to contribute to a broad and established understanding of all aspects of design and to promote the use of results and knowledge for the good of humanity.

The Design Society was founded in 2000, taking on the previous activities and responsibilities of the Workshop Design Konstruction (WDK) Society, especially the organisation of the International Conference on Engineering Design (ICED) series of conferences, which had been running since 1981. Since 2000 the Society has organised ICED conferences in Stockholm, Melbourne, Paris, Stanford, Copenhagen, Seoul and Milan. The upcoming 2017 conference will be hosted in Vancouver.

The Society has members from over forty countries and it organises very popular events such as the Engineering and Product Design Education conferences and the International Conference on Design Creativity among many other activities. The Society is very active in publishing papers and proceedings on design topics, and it has a developing portfolio of other design resources available to members including a repository of theses and collaborative agreements with a number of design research journals.

The Design Society concentrates on activities that transcend national boundaries, and, where possible, will seek to complement national activities. The objects of the Society are to promote the development and promulgation of understanding of all aspects of design across all disciplines by:

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EDUCATION IN DESIGN FOR SUSTAINABILITY AND NEW SOCIAL CHANGES

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ABSTRACT
This paper is an ongoing research study that highlights sustainability and social ventures to create connections between academic and business world to design towards the new functions of XXI century's reality. The authors underline how design practices can help to create a pilot project, implementing social changes. This means that governmental inefficiency presents as a new problem that designers, educators and entrepreneurs must face, demanding to endlessly diagnose the situation. This research proposes to redesign and develop a self-sustainable habitat for minorities, such as, refugees, something that is integrated in the city and not isolated. The issue of building in historic centres is essential to understand the life of the city in a changing world. That is, it is the ability to design systems and not compact and definitive frames. Methodologically, this research is sustained by transversal thinking, pattern-language, and sustainability, connecting established methods with new techniques. The paper presents some cases studies with design students where creative activities transformed the entire urban community. The authors want to prove that designing inclusive systems can serve as a stimulus to attract companies, creating new stakeholders that stimulate new product development and innovation.

Keywords: Reflective practitioners, self-sustainable habitat, pattern-language, co-design

1 INTRODUCTION
Sustainability issues are characterized by complexity and ambiguity as a reflex of liquid reality [1], but there is still unsustainable development due to globalization of resource-intensive economic progress and consumerist lifestyle [2]. To recognized sustainability with a pluralistic view, it is urgent to develop policy instruments, such as sustainable strategies, mutual methods, and collective goals. In view of COP26, sustainability is increasing in importance relative to social changes. Nevertheless, empirical outcomes show that methodologically it is hard to translate into practice in education discussion and that often it is a question of communication rather than sustainability. "We then discuss whether sustainability communication is something 'unique‖' or simply communication that happens to deal with sustainability" [3]. For instance, having a discourse oriented to students, means using communication about sustainability (CaS) as it is an excellent opportunity, a sender-receiver-oriented and one-to-many communication mode, sharing ideas about sustainability [4]. Although, in design education how is it possible to reflect progressive thinking of the liquid reality moving from humanitarian but trivial greening to greater principles of sustainability? Jeremy Rifkin [5] states that today's consumer is no longer in the situation to ask himself/herself whether (or not) he/she wish to have this or that object that he/she doesn't have. The question that ultimately occupy his/her mind is if he/she wants new experiences to live. This new rationality means that communication change, not only rearranges society and human connections, but also social perceptions. Concerning connections in design education, Tomas Maldonado [6] argues that design process might include cooperation and integration dynamics and that means comprising several factors. Either factors related to the use, the enjoyment and the individual or social consumption of the product (functional, symbolic, or cultural factors). Either those factors related to its production (technical-economic, technical-constructive, technical-systemic, technical-productive, technical-distributive). "Industrial design is a creative activity whose aims is to determine the formal qualities of objects produced by industry. These formal qualities are not only the external features but

are principally those structural and functional relationships which convert a system to a coherent unity both from the point of view of the producer and the user. Industrial design extends to embrace all the aspects of human environment, which are conditioned by industrial production" [6]. On one side, as Ezio Manzini [7] argues sustainability must be the meta-project of all Design Research activities and not, as it has been in recent years, a kind of specialized sector, alongside other specialized sectors. Therefore, design process applied to design education includes collective well-being of humanity, environment, and the whole planet [5]. Empathy is an imperative base for the true cooperation and integration; hence it may evidence vital. On the other side, Ingvill Gjerdrum Maus [8] describes two methods to design education for sustainability. Firstly, master-and-apprentice model that focuses on how to design. Secondly, student-centred model where the students are less dependent on the teacher. This means the information is no longer private, but public and required transparency and consistency and it is used, among others proposes to public communication and education [9].

2 AIMS OF THE STUDY

The concept of sustainable development discussed in this study is related to building construction process in design education. This study aims to explore how teachers make consciousness of reflective practice, and their individual experience in being a reflective practitioner [10]. The study also considers the concept of pattern-language [11], as a contribution to the history of design methods in building construction. The concept of sustainability in architecture has been debated under several titles since 1970s. While the concept "environmental design" was used in 1970s, "green design" in 1980s, "ecological design" in the late 1980s and in 1990s, the concept "sustainable design" has started to be used since mid-1990s [12]. In a building construction of sustainability product, it is important to define the materials, the process, the infrastructures, cutting material waste, recycling, guaranteeing energy effectiveness or reducing the preservation costs. Burcu Gulay Tasci [12] states that 50% of the energy produced in the world is consumed by buildings and the other 50% is used in industry and transportation. The 2014 Declaration on Education for Sustainable Development (ESD) practice is focus oriented to the realization of the UNESCO agenda for sustainable development and recognized the potential "(…) to empower learners to transform themselves and the society they live in by developing knowledge, skills, attitudes, competences and values required for addressing global citizenship and local contextual challenges of the present and the future, such as critical and systemic thinking, analytical problem-solving, creativity, working collaboratively… making decisions in the face of uncertainty, and understanding of the interconnected of global challenges and responsibilities emanating from such awareness [13]. Although, there is the absence of and instrument to connect these notions in order education systems fully embrace sustainable development [14]. In fact, the problems of the world do not present to practitioners as well-formed structures [10].

2.1 Students' Teacher as Reflective practitioners

In response to create competent and intuitive practitioners, the paper rethinks education for reflective practice and proposes an innovative structure for sustainability by building construction process, where ESD points will successfully connect to framework the sustainable implementation, combining the authors' practitioner skills, analytical pedagogy, reflective practice and referring to reflection-on-experience [10]. Reflective learning model improves the conscious practice of design. Postulates that reflective thinking addresses practical problems, allowing for doubt before possible solutions are reached [10]. Students learn through and from experience to be reflective practitioners as a means of exercising professional activity. The research critical analyse the concept of reflective practitioner. [15] states the characteristics of reflective practitioners are: 1) Open-mindedness; 2) Responsibility; 3) Wholeheartedness.

2.2 Pattern-language as a sustainable methodology to think city's issues

The study considers the concept of pattern-language as Christopher Alexander [11] states due to the direct influence he has had upon counter-tendency project groups such as Archigram. The concept of 'Pattern language' resided in splitting design problems into patterns, enabling the solution of some of the project subsystems. Alexander's proposition consisted of identifying and solving subsystems that constituted the project's complexity and in connecting every subsystem's pattern among them and the user. "This means you must treat the pattern as an 'entity'; and try to conceive of this entity, entire and whole, before you start creating any other patterns" [11]. In this case, the intuition of associating 'pattern' to a whole of the city becomes a reflection-on-experience practice comparing the exercise of design to an exercise proceeding from speculations, through semantic association, to solve problems that may be concealed or poorly defined. Thus, it is relevant to choose a methodology focus oriented to a part of the city with a strong semantic connotation, as self-sustainable habitat.

3 RESEARCH PROCESS

Today, the phenomenon of liquid modernity [1] presents itself as a complex and fluid truth that conveys disquieting sensations. As Zymunt Bauman states “the most poignant yet the least answerable question of our times of liquid modernity is not 'What is to be done?' (in order to make the world better or happier), but 'Who is going to do it?'” [1]. Therefore, citizens are gradually inclined to recognize their role in the world, helping direct charity. The payment associated with the idea of helping someone causes happiness. Moreover, “the only two useful things one would expect, and wish, 'public power' to deliver are to observe 'human rights', that is to let everyone go her or his own way, and to enable everyone to do it in peace (…)” [1]. Thus, this might be a great opportunity to the cause of refugees.

3.1 Purpose

Refugee camps are defined as “locations where refugees reside and where, in most cases, host governments and humanitarian actors’ provide assistance and services in a centralized matter” [16]. Camps should be the exception, and as much as possible a temporary measure. According to United Nations High Commissioner for Refugees (UNHCR), the process of allowing “refugees to access and live in dignity in secure settlements that improve their social, economic and environmental quality of life as a community and also, enabling refugees to access shelter solutions that provide privacy, security and protection from the elements, emotional support, and a space to live and store belongings in a dignified matter” [17]. The current global crisis encourages unconventional results. This situation allows designers and all community to work together in cooperation to implement pilot and better solutions. According with United Nations Conference on Housing and Sustainable Urban Development report, about 37% of international migration is between developing countries, and around 40% of international migrants have moved to a neighbouring country within their region of origin [18]. Specifically, they move to urban areas and countries are simultaneously places of origin, transit, and destination. In fact, in this study, the elaboration of the purpose creates relevant opportunities to think about design education. While twentieth century design education focused on function and form, the design education debate today focuses on relationships, limits, energies, culture, and sustainability.

3.2 Related work

A case that confirms this research is Kengo Kuma’s interpretation of vernacular construction of Japan. A challenge to identify “local typologies and their responsiveness to micro-local conditions.” [19]. It means the ability to patterns changed in space and to adapt to local and external factors interacting in the process. A pattern may resolve a problem in a way that “you can use this solution a million times over without ever doing it the same way twice” [11]. Constructions should be adapted to places and individual needs, suggesting flexible design to meet the real requests.

Another case that validates this study is Rai Studio and Architecture for Humanity Tehran, in collaboration with the Norwegian Refugee Council. The atelier completed an adobe construction prototype [20]. The construction, built in an Afghan Refugee Camp in Kerman - Iran, had 100-meter square meter domed shelter that was comprised of approximately 6,000 mud bricks [21]. As professor Pouya Khazaeli states “social sustainability in design is our main focus area here. It means to study how these refugees live, communicate, the meaning of privacy in their live, which materials they prefer and use for construction, which kind of construction techniques they use themselves, how much they spend normally to construct their own shelters (…)” [21].

Japanese Architect, Shigeru Ban is a further case. He developed several types of shelters for a pilot neighbourhood. Unlike typical refugee shelters, these structures were made to provide a home for long periods of displacement and the four typologies developed are informed by Shigeru Ban Architects' vast experience with disaster relief projects and the building techniques of local people. “The four proposed typologies were inspired by the building techniques of the nomadic Turkana people and were generated based on extensive research on the vernacular architecture of the region and a comprehensive survey of the refugee population” [22].

Finally, a Portuguese case comprising a space for food preparation to build a seasonal and temporary solution. The project involved a partnership with a Portuguese company, who financed the project [23]. This kind of framework identifies stages in the design process that are influenced by culture and sustainability, and the pattern they are likely to form [24]. The resolution may be implemented through problem-solving in a particular context. In this case, considering the problem of refugee situation.

4 METHOD

In this study, methodology was understood as no linear but cycled process. This is an on-going research qualitative, mixed interventionist and non-interventionist study and integrated a master's in design education programme, including teachers and students. The non-interventionist phase consists of the analyses and interpretations of concepts and historical contents from the past. The interventionist phase resides on a pilot project. An interpretation that includes external factors and is deductive like manufacturing, inductive like self-production, abductive like connecting propositions through practice and a story-telling process like if on is telling a story in a renewal way.

5 PEOPLE, PRODUCTION, PROMOTION

The project was developed in 2016 by 6 teachers (4 architects, 1 engineer and 1 designer), and 1 student from the master's in design of IPVC, Instituto Politécnico de Viana do Castelo. The project consists of a modular resolution for one person. The shelter is a temporary solution for refugees and homeless to use it when they needed it. The project involved a partnership with a Portuguese company, who financed the project. The research applied at an academic experimentation level can become a key instrument to bridge the gap between business and academia. The way teachers make consciousness of their individual experience guide them to become reflective practitioners. Therefore, the student learns through and from experience to be reflective practitioners to exercise professional action. The authors collected and analysed data to define the sustainable habitat with the subsequent features:

- The shelter should contain all the necessary equipment for sleeping.
- The module should have 2,5 x 2 meters.
- The shelter conformation should allow mobility.
- The module should promote and connote sustainability.
- The shelter should ensure open/closed configurations.
- A second module contains a toilet and a shower.
- When not in use, the shelter is easily removable and mobile and relies on municipal water supply, sewage, and electricity. The product presents itself as an innovative solution prepared to reach phenomena of social flows such as the movement of refugees.

The construction of a second module is foreseen, which will encompass the physiological actions related to bathroom space. The process included meetings with the school lieders, the companies, the city-hall, and no-governmental entities. To apply knowledge to practice and, finally to create and develop the prototype, in a first moment, the model was designed and was open to criticism from the student, the teachers and entrepreneurs. Co-design process add value to create students' teacher as reflective practitioners and prompting intuitive practice guided be experience. Concerning materials, it will be used aluminium as it is the main material of the project's partner and because it is easy to clean. The project will be officially during the 2023. The system contains scientific and social dissemination, with repercussions on social networks, and regional press. The next step will be the creation of a partnership with municipalities in the region.

6 PROPOSITIONS FOR DESIGN

With a rising number of refugees and migrants in Europe seeking for better conditions, this self-sustainable habitat encouraged new sustainable models and ask European customers to consume brands for causes. The expense one has with the offering causes happiness, which is a great occasion for today's reality. The sell-sustainable habitat certified students to connect with local companies. Also, it linked companies from different sectors, which had never worked together, stimulating cross-fertilization [25]. The companies were challenged to participate in a project creating new opportunities for change. Teachers and students had the opportunity to interpret precise technologies and materials. Having this new methodology in mind, design students were able to improve new concepts and to cross new experiences and areas of knowledge. The self-sustainable habitat highlighted the technical competences of the materials. In addition, the new product development emphasizes the semantic competence in design, relating black cork with the tubular iron structure, providing hot and cold sensations in a visceral, behavioural, and reflective process [26]. The self-sustainable habitat is an occasion for all to change.

7 RECOMMENDATIONS

Considering the study produced, in the following phase it is recommended:

- To build a local network, connecting different professionals from distinct fields. The project includes a school of design and a research centre, the town hall, local non-governmental associations, material companies and artisans.
- To promote cooperation and co-work. To draw a teamwork system may contribute to create new businesses and join ventures, developing sustainability and competitiveness.
- Methodologically, the research was based on an open and constantly changing briefing.
- To relay other fields and specialists present in the city to create a stronger system.
- To develop the process of generating ideas and creating project hypotheses in partnership with the companies involved. The creation of the project at the prototype level will guide the project at the application level, allowing to timely identify future production errors.
- To create a design process that combines tradition and innovation presents a creative, experimental, and innovative methodology and transfers knowledge to society.
- The academy benefits from the experiences carried out with case studies to be used in future teaching/learning initiatives as a diffused education.

8 CONCLUSIONS

This study emphasizes sustainability and social ventures to create links between the academic world and the business sector regarding the new functions of today's reality. The authors highlight that it is possible to create social changes by creating a pilot project, relating design students and entrepreneurs. Also, the paper rethinks education and offers an innovative structure for sustainability, where ESD points will productively link to framework the sustainable achievement, combining the authors' practitioner skills, analytical pedagogy, reflective practice and suggesting to reflection-on-experience. Considering the translation of people, the social phenomenon of refugees that qualify today's reality, the authors presented a self-sustainable habitat designed and developed with master design students and businessmen. With this idea in mind, it is possible to educate students to become good designers, if one educates them to become better citizens. For students the project was an occasion to interpret specific technologies and materials. Students were able to create new concepts and to cross new experiences from different areas of knowledge. In fact, the worth today could be the universal key to identify new bounds of quality. For educators this plan was a chance to think about design education, developing connections with other professionals, promoting job rotation and cooperation. In fact, the development of design depends on the ability to connect education with research and profession. For manufactured industries the creation of this self-sustainable habitat is an opportunity to change, participating in a new venture. The proximity between entrepreneurs and handcrafters may become strategic for the survival of the above areas. For society, the project may increase the concept of sustainability. It is a productive action that promotes multidisciplinary and interferes in the real world, instead of designing for an imaginary city of the future.

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NON-EXPERT PRACTICAL APPLICATION OF AI VISION SYSTEMS IN DESIGN ENGINEERING PROJECTS

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ABSTRACT
Design projects units for BSc (Hons) Design Engineering students at Bournemouth University integrate and apply knowledge from a range of taught units together with self-directed learning and towards solving design problems. Recently, level 6 (FHEQ) project students have proposed and designed solutions that require AI vision-systems. These projects presented a problem for supervision, with limited, or no expertise in the technology or available equipment; students therefore treated these subsystems as a “black-box” exercise. To address these issues a set of technical requirements were compiled, a range of AI technology solutions were identified before selecting the Nvidia Jetson Nano. From the literature, a stream-lined practical program was developed to introduce the technology to level 5 and level 6 project students as part of their design education. This provided hands on experience through familiarization with the interface and the use of pretrained models before students re-trained networks with their own datasets. Level 5 students utilised the technology to develop a scratch detection machine for sorting damaged components. Level 6 students were provided with the opportunity to integrate the technology into projects where appropriate and two students did so; one developed a device to identify people trapped in buildings after an earthquake, the second developed a device for monitoring chili-plants when grown under polytunnels. Developing and delivering the introductory programme as a non-expert learning pathway has enhanced the student experience within design education, provided a simple workflow that students can utilise and build upon, and led to successful student outcomes.

Keywords: AI, projects, machine learning

1 INTRODUCTION
Design projects are an essential element of design education learning for BSc (Hons) Design Engineering students at Bournemouth University and represent 20 ECTS credits at level 5 (FHEQ) and 30 ECTS credits at level 6. These projects allow students to integrate and apply knowledge from a range of taught units together with self-directed learning and towards measurable outcomes. Through these units, students demonstrate specific elements of the Engineering Council (ECUK) AHEP3 and AHEP4 learning outcomes for accredited degree programmes [1]. For level 5 projects, students design solutions to both individual and group projects meeting the ECUK specification of “broadly defined problem”. Level 6 students work on a single individual design project from their own proposal meeting the ECUK descriptor of “complex problem” and require technical challenge. In either case, students are expected to develop new knowledge in subjects they may be unfamiliar with through identifying their individual learning needs and applying self-directed learning, preparing them for lifelong learning.

2 EMBEDDING AI TECHNOLOGIES
For AY2020-21, a number of Level 6 students proposed final year projects with autonomous control systems, typically navigation or decision-making, requiring artificial intelligence (AI) vision-systems integrated to control system. These projects presented a problem for supervision, especially during the recent pandemic, as students had received no prior learning in the technologies, and the department had limited expertise or experience of AI technology. Students therefore treated these subsystems as a “black-box” [2] exercise within their project, rather than developing hands-on experience of integrating AI technologies and enhancing their design education experience.

The need to develop capacity for AI learning within the department aligns with findings from the literature. Miranda et al [3] found AI/ML to be a core component of technology and competency for meeting Education 4.0. Laupchler [4] identified the importance in improving AI literacy of non-experts in higher education. Nakhle [5] identified the importance of AI in phenomic image analysis and the dependence upon data scientists, and present an interactive tutorial to aid researchers without coding experience. Essentially, AI literacy is an essential skillset in engineering design education.

2.1 Review of student project requirements

A number of Level-6 students from 2020/21 designed projects embedding AI systems as a "black-box" within the control-system. In each case students provided an outline specification of expected outcomes (function) and specified a suitable technology (means); all students lacked detailed knowledge in the subject area to specify how the technology might satisfy those outcomes.
Level-6 final year projects embedding AI systems as a "black-box" model were identified together with the black-box function and proposed technology; each project was subsequently ascribed a suitable means and minimum performance in frames/second (Table 1).

Table 1. Level-6 project function-means translation

Project	Black-Box Function	Technology	Means	FPS
Beach Cleaner	Identification of beach waste	Vision system	Object detection	20
Paddock weeder	Identification of poisonous weeds in a horse paddock	Vision system	Image classification	40
Pothole Detector	Identification of road surface damage	Vision system	Object detection	40
Marine surface cleaner	Identification of floating waste in marinas	Vision system	Object detection	10
Automated medical supply unit	Navigation within a Hospital	Vision system	Semantic segmentation, integration to ROS	20

Values identified within the table are estimated and dependent upon image size, camera orientation and rate of image variance. For example, Asad et al [6] found that a Yolov5 neural network retrained as a pothole detector achieved an accuracy of 90% at 38.9FPS when tested against a video stream from a vehicle travelling at 65kmh (40mph).

2.2 Suitable AI ecosystem

A study of available AI ecosystems was conducted in order to provide students access to suitable equipment, knowledge and learning opportunities. Key objectives were: availability, cost, extent of ecosystem, transferability of skills, range of vision process techniques, ease of system-training, track record, deployability. Although the current market is now well served, at the time of the initial investigation there were limited options available that could meet the objectives (Table 2).

Table 2. AI system attributes

System	Advantages	Disadvantages
Google Coral USB accelerator	Low-cost. Compatible with Linux or Raspbian. Wide range of pre-trained AI models. Trains off-board using Google Co-lab & Jupyter notebooks. Good performance. Wider ecosystem includes developer boards.	Poor availability when required. No semantic-segmentation retraining option. Limited range of models. Requires training off-device. Requires a mini-computer for edge operation.
Intel Neural Compute stick	Low-cost. Compatible with Windows, Linux or Raspbian. Wide range of pre-trained AI models. Trains off-board through open-vino using Intel based PC. Good performance.	Poor availability when required. Training workflow is non-intuitive. Requires training off-device. High level of technical knowledge required. Requires a mini-computer for edge operation.

Nvidia Jetson Nano	Good availability. Low-cost. Linux developer board with GPIO. Extensive ecosystem, including learning materials. Used extensively industry. Wide range of pre-trained AI models. Trains on-board & off-board. Very good performance. Simple to integrate into control systems using Python.	Availability limited throughout 2022. Recommended off-board training requires Linux PC with 32GB Nvidia GPU or similar cloud instance.

From the evaluation it was clear that the Nvidia system held significant advantages in workflow, capability and useability; crucially, they were available. Seven developer boards together with cases, PSUs, SD cards and fans were purchased for evaluation and curricula development.

2.3 Deep Neural Networks on the Jetson Nano

The Jetson Nano provides two practical routes to deployment of a range of Deep Neural Networks (DNN): Jetson-Inference, and Deepstream SDK.

2.3.1 Jetson-Inference (Hello AI World)

An Nvidia package of DNNs and runtimes and vision libraries for inference on Jetson devices. This package provides ten image recognition models, ten object detection models, eleven semantic-segmentation models and three pose estimation models (Figure 1). The package includes Pytorch [7] for transfer learning (retraining) of image recognition and object-detection DNNs onboard the Jetson.

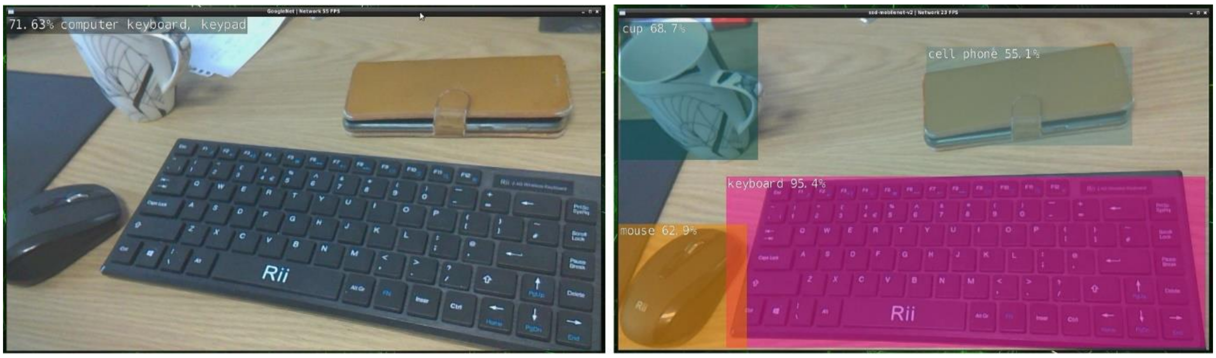

Figure 1. Image recognition (L), and object detection (R)

2.3.2 Deepstream SDK

A streaming analytics toolkit capable of deploying multiple DNNs across multiple video feeds with features such as object tracking and other sensor data. Industry standard DNNs can be downloaded from the Nvidia model zoo, trained off-board on an Ampere GPU equipped Linux PC, or trained in a cloud instance such as Azure.

3 NON-EXPERT LEARNING OF PRACTICAL AI

Familiarity was gained through Nvidia Deep Learning Institute training courses [8]; experience here was distilled to two generalized workflows and supporting materials for a range of student use-cases:

1. Deploying pre-trained networks for classification, object-detection, semantic-segmentation, or pose estimation.
2. Retraining existing networks for custom use-case and deploying for classification or object-detection.

Although Deepstream was evaluated alongside jetson-inference, the procedure for deployment of custom models was found to be more complex than for jetson-inference. Therefore, both workflows were developed exclusively through the jetson-inference package.

4 PRACTICAL EXPERIENCE FOR PROJECT STUDENTS

All project students gained practical experience in small groups through hands on familiarization of the Jetson Nano and deployment of pretrained DNNs for object classification, object-detection, semantic-segmentation, and pose estimation. Following the introductory training, Level-5 students go on to develop a practical application through retraining an object-detection DNN described below. Level-6 students that required AI control within their project were provided further learning opportunities in transfer-learning and python script editing to assist with their specific use-case.

4.1 Application to Level-5 student group project

For the level-5 group project, students from both AY2021/22 & 2022/23 cohorts were tasked to design and build a part sorting machine that detects un-scratched and scratched plate components (Figure 2), sorting them into separate output bins.

Figure 2. Un-scratched plate (L), and scratched plate (R).

The scratch and plate were detected utilising the Jetson Nano with overall system control provided by a Schneider Electric M221 PLC.
For the AI workflow (Figure 3), students collected and annotated (labelled) more than 200 images, using the Jetson camera-capture tool to create their own ground-truth in the pascal-voc format [9].

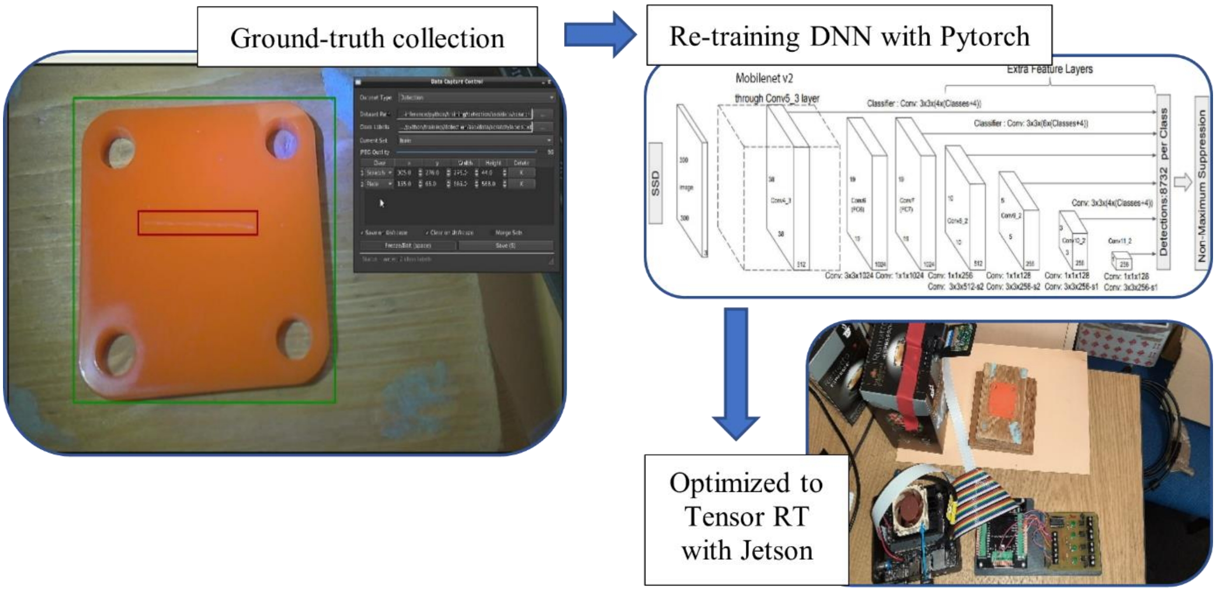

Figure 3. Jetson transfer-learning workflow

Students used the ground-truth to retrain SSD-mobilenet-v2 [10] onboard the Jetson using Pytorch through 80 epochs (training loops) before exporting to an open neural network exchange (ONNX) data format [11]. The onnx file can then be called by a python script that optimizes to the Jetson Nano's Tensor RT format before running as an object detector. The Nvidia provided script can be further customized to extract key data from the detector (object class, confidence, co-ordinates) for specific actions as required, such as signalling to the PLC over GPIO.

4.1.1 Level-5 outcomes

All project groups from AY2021-22 and AY2022-23 successfully retrained the DNN with their own ground-truth. However, 2021-22 students initially struggled to improve their model performance during training due to human error in mislabelling of detection classes. Students were able to correct these errors by utilisation of third-party labelling tool CVAT. The experience in label errors led to revising the student learning for 2022-23; here the initial ground-truth was treated as a familiarization exercise to emphasize the care required in the labelling stage hence DNN retraining was more consistent. One group from each AY successfully demonstrated a fully integrated system (Figure 4).

Figure 4. Typical student plate detection sorting machines

The most common problems were related to the plate loading mechanisms, not the AI implementation. Where the DNN did have performance problems it was typically misclassifying the background, when no plate was present, as containing a plate. Again, this was due to poor control of the training environment; typically, a lack of variation in backgrounds used during the collection of ground-truth images. Students had not constructed the hardware before training their DNNs, therefore training images could not be captured directly from the sorting machine. Where students varied the background, with random objects in-shot during capture of ground-truth, they had fewer misclassifications of detection.

4.2 Application to Level-6 student final projects

Two students used AI tools within their 2021-22 final year projects. Both students developed their applications using the Jetson Nano after completing the familiarization training outlined above.

4.2.1 Chili monitor

The first student designed an autonomous device to monitor chili pepper plants and identify when the fruit was ripe. They followed a similar procedure to the level-5 group project to develop their technical demonstrator and identified the limitations of the DNN pipeline; it was not possible to count the chilis, but the student did identify how the same methods could be used with Deepstream to achieve this.

Figure 5. Chili monitoring robot, detection (L), design (R)

The demonstrator operated successfully after retraining the mobilenetSSDv2 DNN with a limited number of images to detect ripe and unripe chilis. Similar to the group projects of 2021-22, the initial re-training was hampered by mis-labelling and limited quality ground-truth. Attempts to correct this were hampered after CVAT became unavailable with the withdrawal of Intel from their Russian operations but overcome with additional images from fresh plants and data checking using another 3rd party annotation provider, Roboflow.

4.2.2 Earthquake building search tool

The second level-6 student developed a tool for locating victims trapped in earthquake damaged buildings. In this case, the object being identified was a human, therefore a standard pre-trained network would be suitable for the task. The student experimented with a range of both object detection networks and semantic segmentation networks before selecting the multi-human-parser (MHP) segmentation network [12]. This utilised the jetson-inference pipeline with the original python code edited to provide GPIO output from threshold values for particular classes as a percentage of screen pixels. For the MHP network this was used to signal the presence of classes such as arm, leg, hair, face, body. The final design featured a series of lamps for body-parts, a screen for visual verification and telescopic camera manipulator to reach into enclosed spaces.

5 FINDINGS

The introduction of AI tools through non-expert experiential learning has been successful. It has enabled a pathway to deploying advanced technology in design engineering projects without the need for technical support from data scientists and only a basic knowledge of coding. Both Level 6 students benefitted from developing their knowledge on the same learning journey as their supervisors, a shared experience. Level 5 students were able to explore the possibilities of the technology without risk or detriment by learning through the shared experience of a group project where overall technical success or failure was not a significant part of the marking criteria. However, there were three principal weaknesses in the project experience:

First, the lack of verification tools (or complexity of) for pre-checking and correcting object-detection ground-truth on the device.

Second, level 5 students failed to adequately plan their work, underestimating time for building and testing of hardware elements.

Third, difficulty in obtaining hardware over the period 2021-23, although this appears to be in line with availability of many micro-processors and micro-controllers.

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WORK RELEVANCE IN CIVIL ENGINEERING EDUCATION

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ABSTRACT
The Norwegian government states in the white paper “Education for restructuring – increased working relevance in higher education” (Meld. St. 16 (2020-2021)) that to prepare students for the jobs of tomorrow educational institutions need to decrease the gap between the academics and the industry. An internship can be difficult to organise for some study programmes as it usually involves a considerable degree of effort and time. Hence, this paper investigates what the students consider to be work relevant in their study, and alternatives to internship for the study programmes to better prepare the students for the industry.
Two surveys were distributed at the beginning of October 2022 to all the bachelor and master students in Civil Engineering at the University of Agder: one for the bachelor students and one for the master students. The Civil Engineering Department at the University of Agder has made various attempts to increase work relevance. Despite this, the students still rate the work relevance relatively low.
The result from the surveys indicates that the students find many of the courses and the design of the lectures to be work relevant. The findings of this study suggest excursions, company presentations, laboratory work, guest lectures and projects to enhance the work relevance in a study programme. This study could help study programmes improve their work relevance without going to the extent of implementing internships.

Keywords: Work relevance, civil engineering, education, survey

1 INTRODUCTION
To develop the employees for the future we need to address the students of today. According to the World Economic Forum [1] four types of skills are needed for the jobs of tomorrow; problem-solving, self-management, how to work with people, and technology use and development. The Norwegian government states in the white paper “Education for restructuring – increased working relevance in higher education” (Meld. St. 16 (2020-2021)) [2] that to prepare students for the jobs of tomorrow educational institutions need to decrease the gap between the academics and the industry. Consequently, educational institutions need to increase the work relevance of the courses taught in the study programmes. The Civil Engineering Department at the University of Agder (UiA) has made various attempts to increase work relevance, such as a work-relevant curriculum, exercises, software, exams, guest lectures, laboratory work, company presentations and excursions, to name a few. Even so, when looking at the results from the national student survey “Studiebarometeret” [3, 4] the category with the lowest score for the civil engineering students at UiA is the perceived connection to working life. On a scale from 1 to 5, 1 meaning to a small extent and 5 meaning to a large extent, the student’s rate five claims regarding work relevance in their study programme. The results from 2021 show that the bachelor students have an average of 2.8 which is 0.2 below the national average and the master students have an average of 3.1 which is 0.3 below the national average. Out of all the categories on the survey “Studiebarometeret” work relevance is one of the lowest scoring categories. Hence, this is a common challenge for all universities within the civil engineering educations.
The Organisation for Economic Cooperation and Development (OECD) [5] did a study in 2018 to investigate how students managed the transition from student to employee. The study concluded that Norwegian higher education prepared the students for the industry. However, the same report stated that Norwegian higher education lacks work relevance in their study programmes.

The white paper "Education for restructuring – increased working relevance in higher education" (Meld. St. 16 (2020-2021)) [2] solely mentions internship as a way of increasing work relevance in higher education, but also encourage study programmes to find other ways of introducing work relevance. "Internship in Higher Education" [6] points out multiple challenges in implementing internship programmes, such as diverse expectations, the required competencies to establish a professional practice, inadequate resources from universities and students who struggle to secure a suitable internship experience. Knouse et al. [7] identified that the students with higher grades were more likely to gain access to internships, risking neglecting the lower achievers. However, very little is known about alternatives to enhancing work relevance in the study programme. Therefore, this study tries to investigate what the students find work relevant in their study programme, and thus give other study programmes suggestions on how to decrease the gap between academics and the industry.

2 METHODOLOGIES

The students participating in this study are studying Civil Engineering at the University of Agder. The students are divided into two groups: bachelor students and master students. The bachelor students are in a three-year programme and the master students are in a two-year programme. Some of the master students have finished the three-year programme at the University of Agder and some of the master students are from other universities. On the 26th of February 2023, the study programmes consisted of 244 students in the three-year bachelor's programme and 90 students in the two-year master's programme. During the time of this research, internships as part of the study programme were not available to students in civil engineering education. However, this will be available from the autumn of 2023.

The purpose of the study was to find out what the students find to be work relevant in their study programme. To determine this, two surveys were distributed on the 7th of October 2022 to all the bachelor and master students in Civil Engineering at the University of Agder: one for the bachelor students and one for the master students. The students had two weeks to answer the surveys.

The surveys were distributed in their learning management system Canvas and were made with the survey programme SurveyXact. First, the students were asked about some background information. Second, the students had the opportunity to write in their own words what they consider to be work relevant to their study programme. Next, a multiple-answer question with a set of answer options regarding what activities they have experienced during their study, see Table 2. The question was formulated: "Which of the following have you experienced during your study?". The options were normal lectures, guest lectures, excursions, laboratory work, exercises and exams, project work, internship, company presentations, software, small talk with lecturers and small talk with fellow students. Fourth, the students were asked "How work relevant do you find the following?", and to rate the same set of options from 1 to 5, 1 meaning highly irrelevant and 5 meaning highly relevant. They also had to rate the courses taught in their study overall from 1 to 5 by answering "How work relevant do you find your courses to be?". Lastly, the students had the opportunity to write one or more suggestions on how to increase the work relevance in their study programme.

3 RESULTS AND DISCUSSION

The data regarding the surveys are shown in Table 1. Both surveys were distributed on the 7th of October and contained 8 questions. The response rate was 20% for the bachelor students and 22% for the master students. Two sets of surveys were used to see the differences between the bachelor and master students.

Table 1. Data about the surveys

Educational degree	Distribution date	No. of questions	No. of respondents	Response rate
BSc	7-oct-22	8	49	20%
MSc	7-oct-22	8	20	22%

Figure 1 illustrates what the students answered on the free text question regarding what they consider to be work relevant in their study programme. On this question, 56% of the answers were specific academic courses taught in the Civil Engineering study at UiA.

The next section of the survey was concerned with rating a set of measures and activities concerning work relevance. Table 2 shows how the students rated the work relevance of various measures in their study, that is normal lectures, guest lectures, excursions, laboratory work, exercises and exams, project work, internship, company presentations, software, small talk with lecturers and small talk with fellow students. Predictably, the highest-rated activity is internships. Normal lectures, exercises and exams and small talk are rated lowest. Assuming that this is typically how an academic course is structured, this outcome is contrary to the previous findings shown in Figure 1. However, the students could have meant specific academic courses consisting of project work, laboratory work, excursions, or guest lectures when giving their response to the first free text question.

Figure 1. Word frequency query results on which activities and measures students consider to be work relevant

As stated before, internship was the highest-scored activity but also scored most ratings of 5 (60%). A closer inspection of the results from the bachelor students shows that internship scored 78% when combining 4 (relevant) and 5 (highly relevant). The bachelor students find excursions (88%), laboratory work (81%) and project work (81%) more work relevant than internships. This observation may provide other universities with effective alternatives to internships. As Chu [6] mentions there are several obstacles to overcome before implementing internship programmes. Hence, excursions, laboratory work and projects do not necessarily require competencies or expectations and could require fewer resources to implement. Furthermore, excursions, laboratory work and projects can be organized by academic staff avoiding the possible pitfall of students struggling to secure a suitable internship experience.

The bachelor students rated the work relevancy of guest lectures to be 3.94 and the master students 4.09. According to Metrejean [8], students also find the use of guest lectures to be beneficial. In a survey in 2010, the average rating was 4.06 on a scale from 0 to 5, 0 meaning no benefit and 5 meaning extreme benefit. Hence, the students seem to assess guest lectures as being work relevant and beneficial in their course of study. Inviting guest lecturers should thus be an easy way of implementing work relevance in the study programme.

The students ranked excursions as the second most work-relevant activity with 4.38 and 4.36 from the bachelor and master students respectively. Alas, only 17% of the bachelor students and 36% of the master students reported having had excursions during their bachelors' degree. Payne et al. [9] found that excursions have a motivational factor and can increase the students' interest in a subject. In "The use of industrial networks to strengthen civil and structural engineering education; a survey-based investigation" [10] 66% ranked the motivational outcome as high or very high when asked about the motivational outcome from participating in an industrial network with excursions. These findings show that implementing more work-relevant activities in the curriculum could have several beneficial effects, both as a motivational factor and in reducing the perceived gap between academics and the industry.

Project work can be an activity to develop the skills mentioned by World Economic Forum [1] such as problem-solving, self-management, how to work with people, and technology use and development. The students found project work to be work relevant with an average score of 3.97. Comparing the results from the bachelor students and the master students, amongst the bachelor students 81% found project work to be relevant or highly relevant while only 64% reported this amongst the master students. In "Various forms of executing peer reviews in civil engineering education" [11] the master students showed a much higher independency compared to the bachelor students. Gatfield [12] found that students with prior work experience were less satisfied with group projects than students with no previous work experience. It is possible, therefore, to hypothesise that these conditions contribute to the observed differences.

Table 2. Average results from the surveys with standard deviation in parenthesis

	BSc	MSc	Average
Internship	4.41 (0.84)	4.55 (0.52)	4.48 (0.68)
Excursions	4.38 (0.71)	4.36 (0.81)	4.37 (0.76)
Company presentation	4.09 (0.82)	4.18 (0.75)	4.14 (0.78)
Laboratory work	4.22 (0.75)	4.00 (0.63)	4.11 (0.69)
Guest Lectures	3.94 (0.93)	4.09 (0.94)	4.02 (0.94)
Project work	4.03 (0.90)	3.91 (1.04)	3.97 (0.97)
Software	3.91 (0.82)	4.00 (1.10)	3.95 (0.96)
Normal lectures	3.73 (0.98)	3.55 (0.93)	3.64 (0.96)
Small talk with fellow students	3.63 (0.87)	3.55 (0.82)	3.59 (0.85)
Small talk with lecturers	3.34 (0.65)	3.64 (0.81)	3.49 (0.73)
Exercises and exams	3.75 (0.95)	3.09 (1.22)	3.42 (1.09)

The national student survey “Studiebarometeret” [3, 4] is sent to more than 70 000 students each autumn and is an important indicator regarding educational quality. Still, the civil engineering students from the UiA rated the connection to working life 2.8 and 3.3. The results represented in Table 2 are contrary to the findings in “Studiebarometeret”. Apart from the master students’ evaluation on exercises and exams, all the other activities score higher than “Studiebarometeret”. One could argue that civil engineering students do not receive or participate in these activities during their study but would value the activities as work relevant. However, Figure 2 illustrates which activities the civil engineering students at UiA report that they have taken part in or been exposed to during their bachelor studies. It can be seen from the data in Figure 2 that a significant amount of the students have experienced project work, guest lectures and laboratory work. This observation may support the hypothesis that the students do not have the required information to understand what work relevance is. This could explain the findings in the study by The Organisation for Economic Cooperation and Development (OECD) [5]; the students in Norway are prepared for the industry, but higher education lacks work relevance in their study programmes. If the work relevance in higher education is solely measured by the students’ opinions, this could give a misleading truth. As the results of this study indicate, the students find many of the offered activities to be work-relevant but still rate the work relevance in their study programme low. Exercises and exams have the lowest score but still have an average of 3.75 from the bachelor students and 3.09 from the master students. Looking back at the results from “Studiebarometeret” [4] for the bachelor students, this is still higher than the results of 2.8.

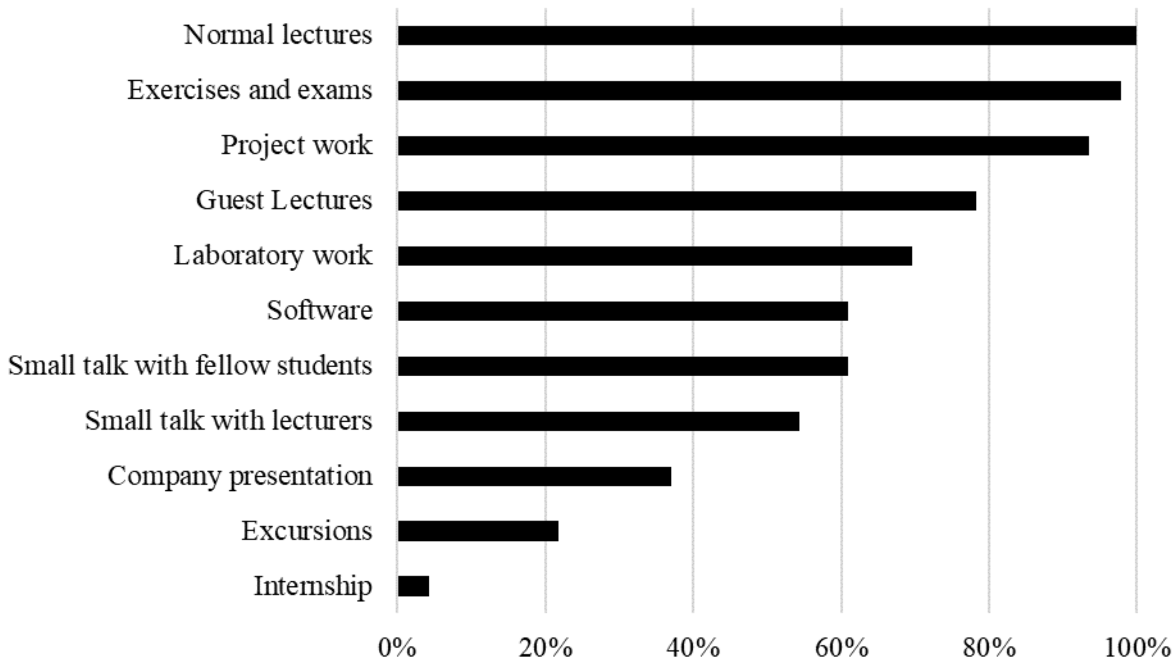

Figure 2. Experienced activities for students during their bachelor study

Internship is clearly ranked as the most work-relevant activity by students, and, as summed up by Chu [6], a number of studies show significant results in non-academic, career and academic benefits for the students participating in internships. The findings of this study suggest excursions, company presentations, laboratory work, guest lectures and projects to enhance the perceived work relevance in a study programme. These activities could be viable and effective alternatives to internships as encouraged by the white paper “Education for restructuring – increased working relevance in higher education” (Meld. St. 16 (2020-2021)) [2].

4 CONCLUSIONS

This study set out to investigate what the students find work relevant in their study programme, and thus give other study programmes suggestions on how to decrease the gap between academics and the industry. On a free text question regarding what students consider to be work relevant in their study programme 56% of the answers were specific academic courses taught at the University of Agder. The students rated the following activities, normal lectures, guest lectures, excursions, laboratory work, exercises and exams, project work, internship, company presentations, software, small talk with lecturers and small talk with fellow students, high with regards to work relevance in their study. Internship is the highest-rated activity by the students when asking of work relevant activities. However, diverse expectations, the required competencies to establish a professional practice, and inadequate resources from universities and students who struggle to secure a suitable internship experience can be obstacles when implementing internships in higher education. Excursions, laboratory work and project work score higher than internships when combining the results of relevant or highly relevant among the bachelor students. Excursions have a motivational factor and can increase the students’ interest in a subject. There was a significant difference in the feedback regarding project work. 81% of the bachelor students found project work as relevant or highly relevant while only 64% reported this amongst the master students. This study has identified excursions, company presentations, laboratory work, guest lecturers and project work to be viable and effective alternatives to internship when it comes to increasing work relevance in higher education.

The major limitation of this study is the relatively small sample size. This will need to be repeated over several years to identify trends. Also, it would be interesting to distribute corresponding surveys to other universities.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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'ARE WE DOING IT RIGHT? EXPLORING HOW TO CONDUCT ETHICAL DESIGN RESEARCH AND PRACTICE WHEN WORKING WITH VULNERABLE PARTICIPANTS'

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ABSTRACT

As designing with vulnerable users becomes more prevalent, we need to establish guidelines to ensure ethical practices to protect both participant and researcher. Current research would advocate that design research should be conducted with end user groups to ensure that solutions developed meet the needs and expectations of those most impacted by the issues. This approach, however, may not always be ethical or appropriate in design projects at undergraduate (UG) level. Along with many of the standard ethical considerations when conducting research with vulnerable groups there are additional considerations when developing design solutions. Many design projects never reach fruition or may take years to develop a functional design requiring participant involvement over the course of the project. Student projects are not always focused on the implementation of final designs.

This paper explores several case studies of UG product design projects where vulnerable participants have been involved at various stages and to varying degrees. Case study analyses follow a description of these projects. The discussion unpacks key questions such as: when is it appropriate to involve participants? What are the most useful methods to work with participants? When are alternative methods of research and testing sufficient? How can expectations be managed? And what is the payback for people to participate? The paper concludes by proposing a guide for *how* and *when* to involve users as participants in the UG design process.

Keywords: Design research, ethics, product design, design education

1 INTRODUCTION

The impetus for this article stems from the researchers' experiences working with UG students on the BSc. Product Design & Technology programme at the University of Limerick and observing the disconnect between the emergent need for ethical design practices [1][2][3][4] and the limitations of UG students when managing complex engagements with vulnerable participants and recognizing situations where participant involvement is not necessary to move a project forward.

Many vulnerable groups may initially be very excited at the prospect of designing solutions that can improve their quality of life. They may be willing to engage in design projects as research participants or as co-designers across the various design stages. However, there is a risk that these participants may invest their time, knowledge and expertise with great expectations, but end up with little in return. A major ethical concern is that they may feel used, exploited, and let down as projects don't reach full completion, fail to reach the marketplace, or indeed reach the marketplace without addressing the original user needs. Including vulnerable participants in UG design projects must be beneficial to participants beyond the goals of the project, otherwise alternative methods should be employed.

This paper explores several case study projects from UG projects where designers have worked with vulnerable participants across different stages of the design process. The case studies are analysed to uncover the successful ways in which the designers engaged with and involved participants in their design process. Also explored are the ways in which this participation could have been improved or even removed if the burden of participation became overly complex or time-consuming with little reward for the people involved. The researchers collated the key lessons into a guide to which UG tutors can refer as they set design curricula and that student designers can follow as they begin design projects that tackle sensitive issues for potentially vulnerable people.

2 LITERATURE REVIEW

Involving users and experts as participants in design research and design projects is seen as an essential part of the design process to create relevant and necessary solutions [1]. Every participatory design project must be built on a robust ethical foundation and conducted with integrity and rigor [5]. However, when people are involved in a participatory capacity (as experts, users, and other key stakeholders), the parameters of the project are often dynamic and changeable [6]. As such the standard ethics procedure within academic institutions might not be nuanced enough to cover the diversity of activities across the entire design process with the dynamic needs of the participants often overlooked. A participant can be involved in more than the initial primary research stage, having a repeated role in the subsequent stages of ideation, concept development and implementation across a practice-based design and research project. Conversely, the ethical approval process might be protracted and overly complex for shorter projects particularly at UG level [7]. As such the role of the participant needs a clearer definition and factors impacting and affecting their involvement must be considered carefully at the outset of any design project.

Working with users as participants introduces a complexity to design projects and this is further magnified when the participants are classified as vulnerable. Unfortunately, there is no consistent definition of a *vulnerable participant* in a research or design context available across international policies [8]. Vulnerable participants can include racial and ethnic minorities, people with additional physical or cognitive needs, elderly individuals, and children [9]. Vulnerability is individual and context dependent, and everyone may be impacted by different and often multiple vulnerabilities [10]. The NHS defines a vulnerable adult as *'any adult (person over the age of 18) unable to take care of themselves or protect themselves from exploitation'* (ibid) whilst the Irish Health Service Executive (HSE) offer the definition of a person who *'may have difficulty and need support in making decision'*. These vulnerabilities thus may affect prospective participants' ability to understand, consent and participate in a design project [11].

Whilst the inclusion of vulnerable participants can add perceived complexity to a project, every effort should be made to include eventual users as participants in design projects. Exclusion doesn't serve either the person or the design process as key insights, needs and perspectives may be missing, and the final outcomes not fit for purpose as a result [12]. Vulnerability must be viewed beyond an individual's ability to consent, but more as a relational factor stemming from power imbalances, potential for harm, cognitive ability, interpersonal relationships, cultural variances, and social imbalances [7][13]. The broadening of inclusion factors will ensure better and more responsible engagement with users and create the potential for an elevated level of trust with participants to continue to engage in design research and testing.

Designers must explore the potential varied vulnerabilities of their participants ahead of the project and develop protocols that are cognizant of, and work to eliminate, minimize or rebalance any risks. They can then put protective measures and protocols in place to decrease the likelihood of harm to a participant and instead empower and promote agency for the participant [7]. Several researchers have highlighted that participants must gain from their involvement and these *user gains* may have personal and/or collective benefits. In addition to reimbursement for expenses and time, non-financial payback can include participants building their knowledge, feeling empowered, gaining agency by having their voices heard, pride in participating and the experience of working with others and potentially helping others in similar situations in the future [13] [14].

Whilst UG design students are encouraged to involve users in all stages of their design project, the complex nature of participatory methods with vulnerable users presents challenges [7]. Ethics cannot be overlooked in educational projects to produce competent and ethically aware professional design community (ibid). At UG the designers are still amateurs, they might not have the skills to manage sensitive situations, their projects are not likely to develop into fully realized designs and testing might be exploratory without leading to a specific solution. Modified Ethical Approval processes can be developed for UG projects, but what appears to be missing from current research are practical guidelines for design students to help them plan and implement rigorous and responsible design projects and to offer workarounds when access to participants is not available or advisable.

3 METHOD

A number of undergraduate product design projects were chosen as exploratory case studies. The projects are the work of final year UG on a [course name removed]. Therefore, a certain level of design experience and standard of work was assumed. Each case study was chosen because the intended users were classified as vulnerable and in some or all cases participants were involved in the design process at different stages. The level of involvement varied across the projects due to access and availability of participants, designer engagement and project direction.

The case studies were retrospectively studied. The main sources of data were the project process books which document the entire project in both visual and written format. The process books were analysed, and this data was triangulated with notes from design tutors taken during the projects. Through examining these cases the researchers could explore the process undertaken by the designers for research and design development, the methods they used when working with participants across all project stages and the measures undertaken or overlooked, when working with these vulnerable participants.

3.1 Case Studies

Each case study was chosen because the designers were working on topics that were considered sensitive and therefore the intended users were classified as vulnerable users.

Table 1. Case Studies

Case study	Project Theme	Types of participants	Participatory methods used	Alternative methods used
1	Menstrual cup and cleaning system	People who menstruate. Clinical experts	Purposive sampling. Interviews. Focus groups.	Forums & online blogs. Simulated testing with proxy user.
2	Active Birthing device for homebirths	People who have given birth. People who may give birth in the future. Experts & clinicians in birthing process.	Snowball sampling. Interviews & Focus Groups Expert interviews. User testing	Forums & online blogs. Simulated user testing with proxy users. Retrospective interviews (past experiences).
3	Time management and scheduling device for young adults with ASD (Autism Spectrum Disorder)	People with ASD. Carers & guardians of people with ASD. Service providers for people with ASD. Experts in ASD.	Convenience sampling. Interviews. Storytelling. Journey mapping.	Simulated testing with proxy users. Empathy research. Online forums.
4	A navigation device for people with visual impairment	People with visual impairment. Experts. Service Providers.	Interviews. Observations. Journey mapping. A Day in the Life	Empathy research. Simulated testing.
5	Way-finding system for dementia center in the context of destigmatization	People with Alzheimer's, Residential care providers. Professional carers. Familial carers	Site visits. Observations Expert seminar. User interview. Guided tour. Expert interviews.	Journey & empathy mapping. User testing with proxy (non-vulnerable) participants
6.	Applying music as a learning tool to develop social, communication and musical skills, for children with ASD	People with ASD. Experts (music therapists, Special needs assistant, community music teacher).	Interviews. Day in the life. Role-playing & evaluation of concepts with users (teachers & children).	Journey and empathy mapping. User testing with proxy (non-vulnerable) participants. Role play

4 FINDINGS

In the following section we reflect on the findings from the case study analyses which are briefly discussed and followed with guidance for both design tutors and students.

4.1 Ethical 'Approval'

UG research design projects should undergo some form of ethical review. At a minimum, plans and protocols for how and when participants are involved should be prepared, project purpose and participant role(s) clearly explained, and consent forms signed by participants or guardians. Design educators can manage this process, but they would require ethics training themselves to ensure they can make informed decisions on the risks involved. Ethical approval can therefore be a less rigorous process with the tutors acting as the key decision-makers in the process but students gaining experience in ethical practice [7].

Guidelines:

- *Ethical training is essential for design educators.*
- *Formal but 'lighter' ethics approval must be sought that outlines plans for participant involvement, highlights any potential risk and describes measures to overcome these.*

4.2 Recruiting participants

Recruitment of potential users as participants proved difficult for UG designers and was further complicated when the topic was sensitive, and the potential users identified as vulnerable. The most common method was convenience sampling [15] where the designers drew on existing networks (personal and professional) to recruit users, experts, and other stakeholders. This was often difficult for students as their own networks were not extensive.

Guidelines:

- *Close tie participants should be balanced with objective or critical participants at key points in the design process (e.g., user testing & evaluation)*
- *Caution needs to be exerted to avoid 'over-using' vulnerable participants across long duration projects. Proxy users could be used to step in for early-stage testing and evaluation.*
- *Snowball recruitment is very effective for expert participants.*
- *Access to participants can be made through liaison and support groups or other stakeholders.*

4.3 Gatekeepers

Direct access to vulnerable users wasn't always possible across all the cases examined. Where access was possible it was typically through a gatekeeper or advocates who had an implicit understanding of the users, their needs, and the most appropriate and sensitive way to engage with them. This person was often a professional service provider or a family member who could also offer insights as a key stakeholder in the area. An example of a gate keeper would be for example a charity such as the Alzheimer's Society where the society can provide guided access to participants. Indeed, many of these gatekeepers were involved in later stage testing and evaluation of concepts if it wasn't appropriate to involve users at these stages.

Guidelines:

- *Gatekeepers or Advocates are essential for engagement with vulnerable participants. This protects both the participant and the designer.*
- *Gatekeepers can have deeper involvement in the design process providing expert feedback throughout.*

4.4 Alternative participants

Mapping the key stakeholders and relationships at the start of most cases, helped designers to identify where proxy or alternative participants could be used in place of vulnerable participants. In Case 1 the designer conducted retrospective interviews with people who had experienced the situation but were no longer considered vulnerable (e.g., former patients). This proved a very useful method of conducting research, reviewing ideas and testing concepts as the risk to the person was eliminated but valuable insights and feedback were garnered.

Guidelines:

Alternative participants might include:

- *Proxy users.*
- *Participants who have experienced an issue but who are no longer vulnerable, for example someone who was a patient but is no longer undergoing treatment or care.*
- *Liaison with support groups, charities*
- *Experts such as those providing services or care for the vulnerable participants can provide user insights where users themselves cannot.*

4.5 Workarounds - Alternative methods

In some cases, the designers independently assessed the need for the participants to be involved to avoid 'overuse' or participant fatigue (Figure 1). Instead, they used workarounds for research and user evaluation and testing that provided sufficient results to make decisions and move the project forward. This dynamic approach to participant involvement can overcome issues where access to the participants is restricted or indeed changes throughout the project process. This is particularly important at UG where the novice designers are at greater risk of mishandling sensitive or challenging situations.
Guidelines:

- *Workarounds should be the first choice where it yields the same results as participant involvement.*
- *Research workarounds: Expert & Stakeholder primary research; Online Forums & Blogs; Empathy research; Scenario Building; Role Play*
- *Ideation & Concept testing workarounds: Proxy User Testing; Simulated Testing; Journey Mapping; User Stories. Role play.*
- *Participation of users is dynamic and must be reviewed at various stages of the process to avoid over-burdening participants whilst also recognizing their interest in sustained involvement.*

Figure 1. Examples of alternative methods (a. personas, b. proxy users, c. vulnerable user testing, d, user journey mapping)

4.6 Giving back

The participant's expectations were not always managed correctly. Feedback loops were not two-way, participation was not acknowledged and little in the way of payback to the participants was considered. Where the designer could 'reward' the participants, buy-in was stronger e.g.one designer gave sweets to young users to thank them for their participation in the concept testing stage.
Typically, UG projects do not develop into fully realized designs, and at times the participants were not aware of this when they became initially involved in the project. This led to disappointment and at times disengagement from the process once the limits of the project were explained.
Guidelines:

- *Designers must be explicit about the type of project being undertaken (UG college project) and manage the expectations of participants accordingly.*
- *Acknowledging the participant's input through continuous feedback loops demonstrates respect and can strengthen involvement.*

5 CONCLUSIONS

Responsible human and life-centered design must involve the key stakeholders in the development of solutions that affect their lives. And the voices of vulnerable participants are as important in this process. However, what is also clear is that designers must conduct these interactions in ethical and sensitive ways and to do this they must develop good practice from UG to carry through to their professional work. Sometimes it is not appropriate to involve vulnerable users in design research, particularly repeatedly over the course of a project. This research has provided a set of guidelines for UG design students and educators when working with vulnerable participants whilst also providing information on alternative research and testing methods that can be applied when it is inappropriate to use vulnerable participants.

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INTEGRATION OF SIMULATION INTO PRODUCT DEVELOPMENT AT AUSTRIAN SECONDARY AND TERTIARY TECHNICAL EDUCATION

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ABSTRACT
Product development today is primarily driven by virtual methods and can therefore be assigned to virtual engineering. Various software systems are available on the market, on the one hand with embedded CAD systems and on the other hand with stand-alone systems. A major challenge in secondary and tertiary education is to combine virtual engineering methods with general engineering knowledge. This results in the quality issue of teaching how to use the software and teaching the generally applicable knowledge behind the software solutions - i.e., the methods must be taught.
At Austrian HTL (secondary higher vocational schools), there is a strong focus on CAD during five years of education. In recent years, some aspects of virtual engineering have been taken up to prepare students well for working life. However, it is widely recognised that this needs to be strengthened. The paper will present the current state-of-the-art and show possible scenarios for improving the current state. At the Graz University of Technology (tertiary level), there is the situation that students have very different prior knowledge at the beginning of their studies (mainly mechanical engineering), as some of them come from HTL. An e-learning approach for CAD and CAE education was introduced in 2012 at TU Graz to counteract this and better adapt the teaching to the student's skills. As a result, a lot of experience and feedback have been gathered to improve the teaching approach continuously. The article shows this approach and outlines future perspectives.

Keywords: Virtual engineering, secondary education, tertiary education, CAE education, FEA

1 INTRODUCTION
The first steps in the field of CAx[1] were taken by Doug Ross in 1950 with the development of the Automatic Programming Tool (APT), which can be seen as the foundation stone for modern CAM systems. At the beginning of the 1960s, Nastran opened up the field of finite element methods [2]. About ten years later, in 1970, the first steps in computer-aided product development were taken, with CAD models replacing conventional hand drawings. In the first years, these models were limited to 2D geometry and extended to creating 3D geometry about ten years later. Since then, computer-aided tools have been developed for almost every subject area, thus providing the foundation of modern product development [1].
Students follow a similar path to the development of CAD tools in Austrian HTL. They also start their education with 2D hand drawings, which later in their education are transferred to 3D models with CAD programs [3]. Students at technical universities in the field of mechanical engineering also follow this learning process. However, the training at the universities does not end with a 3D model of a product assembly. Still, this model serves as a basis for structural-mechanical-dynamic investigations using, for example, finite element analysis (FEA[2]).

[1] The term CAx summarizes Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufaturing (CAM), Computer Aided Styling (CAS), Computer Aided Planning (CAP) and Computer Aided Quality (CAQ) [1].
[2] FEA, an acronym for Finite Element Analysis, refers to a numerical method for solving differential equations in engineering and physics [4].

Through the results from an FEA, for example, displacement, stresses or reaction forces can be calculated and visualised on the previously created 3D model. This is often a moment of great importance for many students as they get a visual representation of the deformations, stresses or forces for the first time in their education. Since this link between the mechanical calculations and the visually easy-to-grasp FEA results in graphs strongly supports the learning process, it can be concluded that using FEA even earlier in engineering education to understand better-taught content can be very important and helpful for the learning process. That was derived from the CAD approaches outlined in [5].

This linked learning could also be used in theory classes in HTL to transfer the results of basic mechanical calculations into a model to make the learned material more tangible. Particularly, advanced-level students possess the necessary theoretical foundations to carry out such investigations, such as analysing stress curves in loaded components or examining deformations on a workpiece. In addition, it can be shown to the students how they can check entire assemblies for their loads with little effort without having to do pages and pages of calculations.

Of course, the field of application of FEA can be taught much further. Still, this paper is limited to dynamic structural-mechanical investigation since this topic is most widespread in engineering and is most tangible in HTL education. For the execution of FEA, the focus is put on the use of FEA in embedded CAx programs such as CREO from Parametric Technology Corporation (PTC), Inventor from Autodesk or CATIA from Dassault Systemes.

This paper's investigations focus on analysing the actual state of CAE education at HTL and Austrian universities. Thereby it is shown which gaps and approaches exist in the respective CAE education and how these can be closed. Since this is a larger topic area, further follow-up papers are planned (shown in chapter 4.2), which will deepen these investigations and approaches and still establish the conclusions to industrial partners.

2 STATE-OF-THE ART

This section compares possible approaches to CAE training. In the attempt to find a comprehensive training concept, a theoretical approach and a practical approach can be derived.

The theoretical approach is taught increasingly at universities [2]. In this scenario, great emphasis is set on the fundamentals of the FE-model theory. These fundamentals cover a broad spectrum ranging from the different mathematical solution variants of FEA selection of the appropriate element's discretisation to the abstraction of mechanical loading. The implementation of a model in a specific FE-Software is not considered. In the literature, no consistent training concepts specify a procedure that deals with the theory and the practical implementation. There are only standardised procedures for model implementation, as described in [4] [6] [7] [8]. However, the combination between theory and practical implementation is only presented very abstractly.

The practical approach focuses strongly on the application of the software packages. This approach is carried out in training courses of companies increasingly, specifically adapted to the CAx software used. The trainees learn the necessary procedures and the application of different tools. The theoretical background knowledge is partly neglected or assumed. The level of experts is often measured by the variety of tools by them and their skill in handling and operating the various programs and not by the underlying theoretical understanding [2].

At first glance, the practical approach appears to be more appropriate for the application and is also justified. The practical approach "promises" that a finished simulation model is available after the specified procedure is finished. This is also true because if all inputs required by the program are available, the simulation program resolves the inputs into a system of differential equations and solves them, so the software does its job per se. However, whether the simulation is able to represent reality depends on the skills of the person creating the model. A good FE engineer is characterised by the fact that he minimises the simulation effort by the correct omission of unnecessary information and still represents all phenomena to be considered. Finally, it should be mentioned that the simulation results alone do not provide any added value if they are not interpreted correctly with the appropriate engineering background and the knowledge gained derived from these results [1]. To do so, theoretical background knowledge is required accordingly. Therefore, CAx training should be more than applying a few "picks and clicks" [9].

Figure 1 shows the classical procedure of FEA generation in a software environment. In contrast, the right side shows which theoretical background knowledge is required to perform an FEA appropriately.

If all steps of the FEA procedure have been carried out correctly, the FEA delivers the stress present in the component. However, this result alone is only of limited value. The evaluation of stresses still depends significantly on various factors such as system knowledge, application area, desired safety factor and other relevant factors.

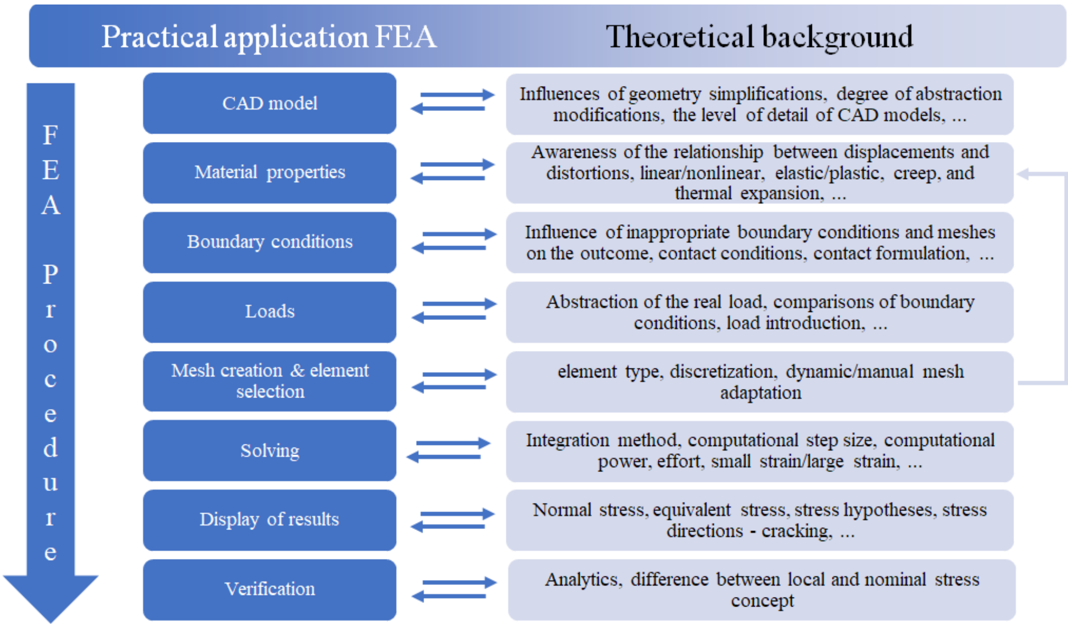

Figure 1. Required FEA theory for implementation in a software environment

To achieve meaningful simulation results, an FEA engineer has to be able to combine and interconnect theoretical and practical knowledge, especially since there is neither literature nor software that can evaluate the results with respect to the existing mechanical system represented by the FE model. An ideal CAx training should therefore combine method knowledge such as understanding the advantages and disadvantages of different CAx approaches, recognising the limitations in the modelling and interpreting results as stated in [2] with the needed practices using various tools and especially interlinking both of them.

2.1 Curriculum TU Graz and HTL

In order to get an overview of the current CAx education, the TU Graz serves as an example, where two hours per week are provided for students in the CAE lecture. In HTL, a capacity of two to four hours per week is available over five years for the design exercise area, which also includes CAD [10]. As universities have freedom in curriculum design, CAx education may differ from other universities of applied sciences. In HTL, there is a uniform curriculum per subject area, which can be designed autonomously within certain limits.

2.2 Actual state TU Graz – CAE teaching concept

In order to give a closer insight into the CAE education at the Graz University of Technology, the course of the CAE education will now be presented. The aim is to link the acquired basic knowledge, such as mechanics, dynamics and machine dynamics, with the working methods of CAE systems and thereby develop an understanding of the application and evaluation of theoretical analysis methods compared to modern simulation techniques. This is ensured by teaching theoretical basics and implementing examples in the areas of advanced CAD methods, finite element method (FEM) and simulation of dynamic systems (multi-body simulation MBS) with selected high-end engineering and CAE tools.
To be able to work with all students from the same foundation, the required theoretical knowledge is prepared in a lecture unit before the practical units, where the application of various simulation software is involved. For students with less prior knowledge, various online teaching resources are provided for self-study. This theoretical knowledge is further consolidated within guided practical units covering practical problems, which are abstracted and solved with the help of various simulation programs. In addition to these practice units, there are also "click-to-click" scripts, practice examples and learning videos on each topic for self-study. This parallel mode of guided practice units and e-learning allows

the students to practice using the software products in self-study, depending on prior knowledge and learning progress. The students are allowed to acquire the necessary contents and skills at a time and speed of their choosing according to their prior knowledge and newly acquired knowledge [11].

2.3 Actual state Austrian HTL - CAE

CAE training at Austrian HTL in mechanical engineering currently comprises more than 550 hours spread over five years [10]. The content is specified by the curriculum, which is jointly prepared by the HTL on behalf of the Austrian Ministry of Education and is evaluated and revised if needed, approximately every five years according to the prevailing educational boundary conditions.

Even though there is a strong emphasis on machinery design based on 2D drawings in training to meet the industry's requirements, the education regarding CAE can be seen as very solid. In the field of CAE, 3D modelling of components and assemblies is focused alongside state-of-the-art design processes as well as classical analytical design processes combined with the use of 3D modelling techniques.

The subject of FEA is taught only sporadically, often depending on the prior knowledge of the teacher. However, the technical fundamentals such as the strength of materials, fluid mechanics and thermodynamics are taught in the theoretical training. A linking of theory knowledge with FEA examples from the strength of materials, solid mechanics, fluid dynamics and thermodynamics is currently not being implemented consistently. The upcoming revision of the curricula starting in Austrian HTL 2023 offers the opportunity to include these important points. The use of CAE programs in theory classes is also being considered, for example, by visualising stress curves in a strength calculation or flow curves in flow calculations. Because Generation Z is strongly oriented towards visual information collection and progressing as well as learning in general [12], there is potential here to better convey the subject matter and to better understand and retain it. Visualising the results of mechanical calculations can help students learn how to apply theoretical concepts to practical applications. Seeing how their work leads to tangible outcomes and that their calculations have a real-world impact can increase their motivation and interest in mechanics.

2.4 Hypothesis - Gaps

Derived from the previously explained experiences, the following hypotheses can be formulated for further investigations:

H1: There are strong differences in the theoretical and practical knowledge of the students.

H2: Only theoretical basics are not sufficient to perform an FEA simulation in a meaningful way.

H3: The interconnection between taught FEA theory and practical application is missing.

H4: Application of theoretical knowledge increases learning success.

3 EVALUATIONS IN TERMS OF THESES

With regard to the hypotheses, this chapter is designed to verify them and should also show where further research is needed.

3.1 Experiences and Evaluations - Tu Graz

Experience in the CAE lectures over the last ten years has shown that students have a wide variety of theoretical backgrounds. To cope with the strong variation in this area, the previously explained CAE teaching concept was introduced at the Graz University of Technology. Statistical surveys have shown that over the last ten years, the content requirements of the course were considered appropriate by 72% of the students, which in turn reinforced the teaching concept. These results come from annual evaluations[3] of the course.

Furthermore, it was shown that even if the theoretical knowledge of the students is at the necessary level, the implementation of theoretical knowledge in practice is a major challenge. This can be deduced from the examination results. Students from higher semesters, who (theoretically) also have more prior knowledge, do not perform better than students from lower semesters.

Another observation, which is made repeatedly, is that it is often necessary to repeat theoretical basics during the exercise units. Therefore, the guided units in the CAE lectures cannot be replaced by

[3] Cumulative result of the course evaluations provided at TU Graz, carried out electronically, by the CAMPUSonline system [13].

instructional videos, tutorials or similar since the knowledge gaps can only be closed in dialogue together with the students and individually tailored to the corresponding students.
At the end of the course, it is shown that students are able to apply their theoretical knowledge to practical tasks. On the one hand, this is needed for the creation of the model, but also for the interpretation of the results.
It is worth mentioning that the aforementioned experiences were derived from strongly subjective, specific long-term experiences and surveys. Collected evaluation results of students from the past ten years serve as a further basis.

3.2 Implicit experience HTL

At HTL, the basics of mechanics are taught in great detail and in an age-appropriate manner. For example, the introduction to solid mechanics is taught at the average student age of 14, resulting in the need for simplifications. For example, forces are "only" considered 2-dimensionally and not spatially via vectors. So, in terms of hypothesis 1, the prior knowledge should be the same for the students. Also, hypotheses 2 to 4 are true from the author‘s point of view. The theoretical basics are clearly established at HTL in the field of mechanical engineering; the practical application takes place in the field of design exercises, but mostly without the use of FEA programs, mostly with the reference of the professors to the basics. The approach is certainly correct for the first strength calculation(s). However, from the authors' point of view, there is nothing to be said against using an FEA program for a repeated strength calculation in the area of design, especially since the analytical verification with the FEA results must always be carried out. First attempts to use FEA in mechanics education in the first classes of the HTL education show quite encouraging results and feedback since the current generation of students is strongly visually influenced [12], and thus the knowledge transfer is positively supported. Analogous to the use of FEA in the field of solid mechanics, an application in the fields of fluid mechanics, thermodynamics and vibration theory is conceivable and reasonable.

3.3 Transfer possibilities

In order to ensure continuous communication and coordination between the individual training programs, a working group consisting of Austrian professors from technical universities (TU), universities of applied sciences (UAS) and secondary higher vocational schools (HTL) was founded with the support of the Ministry of Science and the Ministry of Education. This working group aims to exchange and coordinate the current state of teaching and technology in the field of product development at least once a year in a face-to-face meeting and to develop joint strategies. Due to the different orientation of the individual institutions TU, FH and HTL, a very creative and productive working atmosphere is created in which innovations are made possible and promoted. One outcome is, for example, the participation of HTL in scientific projects at TU or UAS, such as Sparkling Science [14], with the aim of giving young technicians access to tertiary education at an early stage. On the technical side, standardised environments have already been exchanged and further developed in the area of CAD; in the future, this is also planned for the area of FEA. There is a great need for teaching materials and best practice examples, especially within HTL, in order to promote the introduction of FEA.

4 SCENARIOS AND PERSPECTIVES

Finally, this section presents the lessons learned, our further planned work, and an evaluation of the current results.

4.1 Learnings

Based on the evaluation results of the CAE lecture at the Graz University of Technology, it can be recognised that by continuously adapting the course, it was possible to reduce the level of difficulty and the amount of work while maintaining learning success.
Also, at the HTL, the change of the curricula shows further potential to adapt them in order to prepare the students for their further CAE education in the best possible way. Furthermore, FEA can also be used in the area of theory lessons in order to present theoretical knowledge to the students in a more tangible way. For example, FEA can additionally be used in mechanics classes to visualising calculated results such as displacements and stresses directly at the point where they occur on the component and be compared to classical analytical results.

Another finding is that the transfer potential between TUs, UAS‘s and HTL‘s exists but must be further expanded to meet the needs of the industry.

4.2 Aviso Paper-Series – Research design

In order to assess whether it is appropriate to include FEA in the HTL curriculum and which scenarios are feasible and reasonable, a survey is currently being prepared at the HTL. The opinions of teachers regarding different approaches to solving the hypotheses (Chapter 2.4) will be collected and evaluated. Further approaches are derived from this to close the existing gaps in education. These results will be presented in a follow-up paper (Place and time of publication are not finalised now).

In addition, a further paper is planned, which will also address the requirements of the industry. For this purpose, a four-year research project is available, which deals with intelligent, sustainable and human-centred (small and medium enterprises) SMEs[4] and collects their requirements and ultimately develops guidelines for SME‘s 5.0.

5 CONCLUSIONS

Through the research in this paper, the current state of CAE education at schools and universities regarding FEA was revealed. From this, different hypotheses could be derived, which addressed the gaps in education. The CAE training principle of the Graz University of Technology also presented a possible solution for linking theoretical knowledge with practical application.

Other transfer possibilities include the approach to including FEA already in the HTL curriculum. For further investigations in this regard, the design of the corresponding follow-up paper was also presented. In order to direct the focus from teaching to the "customer", the further planned paper serves to show the balancing act between teaching and industry.

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CROSS CULTURAL CO-DESIGNING FOR INNOVATIVE SUSTAINABLE (TEXTILE) DESIGN SOLUTIONS – QUESTIONING SDG 4 & 17

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ABSTRACT
The main goal of the paper is to discuss cultural appropriation in order to ultimately work together to create a more sustainable future and to encourage the application of seven (7) different instruments in educational settings. This paper showcases design methods for co-designing and cross-cultural design processes, to educate students and industry partners about respecting design codes and ownership. A case study on textile design – pertaining to design, production and living conditions – is presented in Europe as well as North Africa, to illustrate the Sustainable Development Goal (SDG) 17 'Partnerships for the Goals' as well as SDG 4 'Education and Quality'. SDG 12 'Responsible Consumption and Production' is supported by our research into cultural appropriation in the design business. 'Cultural appropriation' is not only a debate taking place in fashion design, regarding designers profiting while using patterns that are ethnologically significant to indigenous people without asking permission. Engaging in cultural appropriation with a positive intent can serve as a means of remembrance and 'revaluation' of hand-crafted techniques, which run the risk of being lost. This knowledge is evidence of our cultural remembrance and our knowledge archive for the future: it informs us on how we might restore, teach and convey this valuable knowledge within the curricula – providing a collaborative sustainable design education.

Keywords: *Cross-cultural co-designing for SDG 17, design ownership, knowledge archives for SDG 4, cultural appropriation, 7 instruments for fair co-designing*

1 INTRODUCTION
Our main intention is to design a sustainable future together in Europe and around the globe, while respecting design ownership [1]. We aim to do this by educating students through co-designing with people from so-called foreign cultures. While this paper is an inquiry into cultural appropriation in design, within this framework. It will showcase design methods for co-designing and cross-cultural design processes used to educate students and partners throughout the industry. We are using the elements of edu-care [2] related to our knowledge archives for a sustainable academic future.
Regarding the designing, working, production, and living conditions, the United Nations' Sustainable Development Goals (SDGs) [3] give us an orientation for the future. This paper focuses on the following SDGs: SDG 17 'Partnerships for the Goals' – beyond Europe – with the intention to illustrate how cross-cultural co-designing can promote a healthier world; SDG 4 'Education and Quality' and SDG 12 'Responsible Consumption and Production' are addressed by our question about cultural appropriation in the design business – which examines the cultural education of all partners – and, additionally, reference is drawn to the politically relevant focus selected by the UN for the year 2023. 'Cultural appropriation' [4] originally relates to art robbery and will be explained further in chapter two. Fashion designer Isabel Marant was criticised for profiting from her design, while using indigenous ethnological patterns without asking for permission. However, cultural appropriation conducted in a positive manner can help in the preservation and remembrance of techniques, hand crafted techniques. These techniques run the risk of being lost, which would significantly impair SDG 4 as well on the long with consequences for a sustainable economy. This knowledge represents our 'cultural mind' [5] and our knowledge archive in design engineering, which can be used in the future (see chapter 2.2). Our use of this valuable knowledge archive [6] is showcased using co-design and cross-disciplinary learning in chapter three.

Here, a balance between culture, aesthetics, and ethics – demonstrated by a design study – is achieved. By combining new knowledge connected to rituals, cultural behaviour and old techniques with the technological aid of digital tools of our 4th industrial revolution, we can enter a post digitalisation ‘industry 4.0’ era. Chapter four finally highlights seven instruments used to formulate the cooperation framework applied in design cultures and design studies. The case studies in chapter three will enable you to identify and reflect on the solutions found. This will help you envision and understand how the SDG 17 ‘Partnerships for the Goals’ – beyond Europe – could lead to a healthier world for us, by reshaping the behaviour linked to design attitudes.

2 CULTURAL RITUALS, MIND AND APPROPRIATION – SDG 4

2.1 Cultural appropriation and cultural behaviour – creating a cultural mind

SDG 4 ‘Education and Quality’ and SDG 12 ‘responsible consumption and production’ focus on cultural appropriation in the design business, as directed by the United Nations (UN) for the year 2023. Cultural appropriation is a debate taking place in fashion design. Awareness has been heightened since the misuse of ethnological patterns of indigenous people, in a design by Isabel Marant [7], in the year 2019, as she had not asked for permission.

Cultural appropriation originates from art history, which exposes the phenomena of ‘art theft’ [8]: Over the course of history, emperors took trophies as art objects from foreign countries, indigenous people, and appropriated colonies. The art historian Bénédicte Savoy is highly respected for her expertise on this subject. She published her dissertation about art theft committed by the French in Germany around 1800. In her writings, Savoy explores the sociological, historical and cultural significance of cultural appropriation caused by art robbery. She was invited to work alongside interdisciplinary teams to build the new Humboldt Forum in Berlin. Together with David Blankenstein, she curated a highly regarded ‘Wilhelm and Alexander von Humboldt’ exhibition at the Deutsches Historisches Museum in 2019. The textile example of the balloon, which represents a flight between ‘old and new’ European fields, sparked a vivid discussion about cultural ownership [9]. Savoy and other scientists campaigned for stolen objects to be returned to their original owners. Since this debate, museums in France and in Germany have acted according to their wishes. For example, the Rautenstrauch-Joest-Museum in Cologne are giving back the Benin sculptures, which is part of building the identity of the Edo culture and a significant part of the cultural mind of the folk of Nigeria [10].

Previously, this was meant and understood as the cultural spirit and rituals that shape tomorrow's cultural behaviour, and the rituals that will guarantee sustainable life on earth if craft skills are lost, due to the loss of knowledge regarding physical skills and resourcefulness [11]. ‘Nous sommes en train, d’oublier, peut-être, le métier de physique dans le métier de design’ [12]: We may currently be in the process of losing the physical skills in the design profession, and the part of the knowledge archives connected to objects – such as art sculptures and design objects.

2.2 Co-designing and usage of intercultural knowledge archives

The cultural mind of a nation showcases their long-lasting rituals and passes them along to future generations. It is our cultural code, identity, and knowledge archive [13] that inform our design and handling instructions and are always reflected in the future in terms of the lifecycle of our resources and nature [14]. The textile cultural mind and heritage refers to the phenomenon of cultural appropriation with regard to the question of design ownership. To take the next step toward 21st century design, we need to take cultural appropriation seriously. The case study noted below showcases an example of co-designing in a sustainable and culturally appropriate way. This illustrates how a beneficial cooperation and integration of all partners from different countries, with different cultural habits and understanding, could serve as an example of positive cultural appropriation for the future. We can learn from other cultural codes. We can learn to design form, patterns and design structures, as well as convey the appropriation of old handcraft techniques. Manufacturing knowledge and design is our foundation and, around the globe, we have to learn to value these parts of our societal mind, while conveying the different perspectives.

3 FACING CHALLENGES AND OPPORTUNITIES IN INTERCULTURAL CO-DESIGNING WITHIN SDG 17

3.1 The unfolding of co-designing is breaking cultural boundaries

Social co-designing is becoming an increasingly important area in the design education system [15]. Cultural exchange has the potential to enhance the unique quality of identity, especially when it comes to intercultural co-designing based on a high level of tolerance of ambiguity [16]. At the same time, it enables us to re-evaluate our mindsets, ideas and judgements, thus building knowledge archives [17]. A broader perspective on different cultures of memory leads to a more open and panoramic view of how value attitudes develop [18]. Furthermore, intercultural co-designing can not only drive innovation, but also promote social lifestyle changes towards more sustainability and the transformation of the new economy [19]. A sophisticated design research methodology within intercultural co-working can enable the creation of designs that revive cultural codes and create awareness of the respective culture. They can also meet the aesthetic demands of the target customer [20]. The case study of the intercultural project ’Indigenous Modernity’ will illustrate this thesis.

3.2 Prerequisites for intercultural co-designing of the individual

In order to co-operate successfully with stakeholders from different cultures and avoid cultural appropriation within the discipline of cultural creativity, several preconditions are required. Regarding design creation, a designer should not only be creative, but also respect and possess knowledge of the cultural past and historical political power relations. Thus, it can be ensured that ethnic groups or indigenous peoples are not marginalised or oppressed [21]. To avoid cultural appropriation and to build social-cultural awareness, we must teach history, cultural diversity, and cultural sustainability within the SDG 4, as early as infancy. According to the 2022 Report ’Re|Shaping policies for creativity’ by UNESCO, SDG 4 ’Education and Quality’ aims at the acquisition of the necessary skills, like technical and vocational skills for employment, decent work and entrepreneurship in the cultural and creative sectors, by youth and adults [22]. The key findings of the case study with regard to the prerequisites for successful cross-cultural cooperation are summarised in Figure 1a.

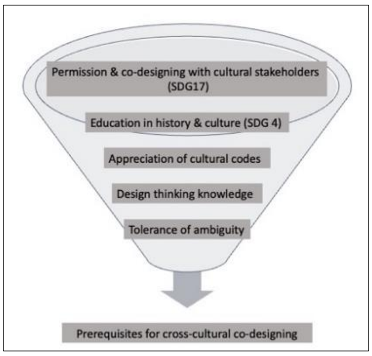

Figure 1a - 2022 Prerequisites for woman in intercultural co-designing-by Charlotte Weber

Figure 1b - Exchange with indigenous Berber Matmata, 2022, photo rights: Ramona Möllers

3.3 A case study of cross-cultural co-designing

The 2022 Summer School project with the co-working collection ‘Indigenous Modernity’ serves as an example of intercultural exchange between multicultural partners. The sustainable denim collection was created by two German design students who co-designed with the Tunisian denim supplier Sartex Group. They collaborated with indigenous Berber people (see fig.1b), the Hochschule Niederrhein University of Applied Sciences, and native Tunisian student Oussema Haddar. The collection offers a combination of modern, innovative textile techniques inspired by traditional cultural rituals, clothing and aesthetics. Such clothes were inspired by representatives of the Tunisian Berber culture and Tunisian historians. The symbolic tattoos of the Berber people served as inspiration and were respectfully transferred into the collection by implementing a profound design methodology. Referring to chapter 2.2, these tattoos of the Berber people can be seen as cultural codes and part of the cultural DNA that are handed over to the next generation. The aim of the project was to revive Tunisian culture, history and tradition with the opportunity to remember and cherish the culture, thereby ensuring that these

important roots of Tunisian history and traditions are not forgotten. Simultaneously awareness of the culture can grow as it is spread. This design study of the Berber culture showcased the co-designing process with stakeholders of different cultures. This required efficient communication on eye level between all parties involved, as well as an open-mindedness towards other cultures [23]. Finally, the collection debuted at Tunis Fashion Week in the desert at Touzeur, in November 2022.
Establishing sustainable cross-cultural collaboration necessitates conducting interviews with representative indigenous communities to gain insights into their cultural and traditional practices, thereby enabling appropriate communication. Additionally, it is indispensable to ask the cultural representatives for permission to use their cultural codes and understand the meanings of spirituality, religiosity and fertility, so they can be encoded or integrated into the designs [24]. The avoidance of cultural appropriation and the loss of authorship can thus be ensured.

3.4 The challenge of different aesthetic perceptions in fashion and textile design

When it comes to co-designing with multiple cultural stakeholders, we face several challenges within the communication and realisation process. As a medium of cultural identity, fashion and textiles can be seen as an important part of this process [25], especially regarding the fundamental differences between Western and non-Western clothing. The non-western fashion is mostly seen as a perpetual costume associated with profound cultural meaning, identity, group membership or religiosity. In contrast to this, western clothing is fast moving, superficial, and mundane, and it projects personal identity. Over the past decades, the term exotic fashion has established itself in Western culture. Grant David McCracken, a Canadian anthropologist and author, defined this movement as ‘selective borrowing’, as early as 1985. Jennifer Craig, who is an expert in fashion theory and cultural studies, notes that such undertakings may be considered institutionalised plagiarism between different subcultures. Moreover, non-Western clothing continues to evolve under its own resilient cultural dress code, further adopting its own version of Western fashion [26].
As the case study in co-designing and the theoretical comparison has proven that different cultural realities on aesthetics in design must be taken into account and respected in order to be able to compete sustainably in the international globalised market.

4 CULTURAL APPRECIATION AND RESPECT FOR DESIGN OWNERSHIP BY USING 7 INSTRUMENTS FOR SUSTAINABLE & FAIR CO-DESIGNING

4.1 Cross-cultural co-designing as curriculum benefit for a valuable cultural appreciation in design

Evolving lifestyles and transitions demand a stronger commitment to international cultural cooperation and openness to diverse cultures [27], including adaptions in curricula and the competencies to be taught. In this respect, cultural co-designing plays an increasingly important role in stimulating and communicating social, economic, and environmental sustainability [28]. Especially in the sense of SDG 17 ‘Partnerships for the Goals’, which calls for more creative intercultural co-designing communities for sustainable development to be established in the future. Therefore, student projects, such as the example of the Design Summer School in Tunisia, must be offered by universities and cooperation partners at an early stage. According to the latest report by UNESCO, the fields of climate strategies and environmental policy should increasingly focus on such collaborations, as they have the potential to initiate much-needed changes in ways of mindsets, behaviour and integration. For the transmission of this kind of knowledge, interculturality, creativity and education must go hand in hand, to achieve sustainable development – as outlined in SDG 4. These aspects should be considered collectively, from early childhood education to curricula in higher education [29].

4.2 Implementing 7 instruments of performance for progressive cultural co-designing

‘Europe needs a new generation of designers, who are able to reshape behaviours as well as empower and help people walk their way towards a more sustainable lifestyle.’ [30]. This is not only an issue for our future rituals but also often unintentional subconscious design attitudes [31]. In this research study our main intention is sketching a sustainable future in co-designing together with different stakeholders and cultures. Respecting design ownership and the textile cultural heritage of other human beings from *foreign* cultures in Europe and around the globe, means educating through co-designing and learning how to integrate people from different countries with different aesthetic values. In summary – as it relates to the SDG 4 and 17 – we can formulate the following wish that underlines our common goal: The summer school case study of innovative sustainable textile designs has proven that the cross-cultural co-designing process is the next generation of sustainable approaches involved in the 4th industrial revolution. On the one hand, our new knowledge is connected to tradition, cultural behaviour and old techniques, while on the other hand, we are connected to advancing assistive technologies. Through the digital tools of the 4th industrial (digital) revolution, we are entering the post digitalization era and textile industry 4.0. We are also connected to academic fields in 'non-hierarchical designing landscapes' [32]. This is the pre-requisite for co-designing and cultural integration, learning about design provenance and ownership, as well as showing respect toward cultural codes (representing sustainable benefits for SDG 4 and 5). In the end, CAD designing, laser-techniques, and interactive designing togetherness on different media levels, give us the technically sustainable tools and -capital linked to human capital. When it comes to design from 'foreign' countries, cultural respect is critical. Our discussion and study have proven that the following seven instruments meet the needs for the sustainable circular (textile) economy of the future:

- Revaluation of and convey the (textile) crafts techniques and traditional codes
- Co-designing together with all integrated partners and stakeholders – collecting experiences through projects early on within the studies
- Creating a unique knowledge archive with 'foreign' countries, which leads to respected knowledge banks
- Revaluation of analogue tactile abilities as a part of small exercises throughout the semester
- Respecting design ownership and design rights by discussing the solutions together
- Integration of all partners early on in interdisciplinary projects – matrix management
- Managing transparent communication as a part of design project management, to serve the SDGs – and, consequently our earth and life.

It follows that these cross-cultural co-designing instruments have to be integrated into curricula.

4.3 Cross-Cultural Co-Designing – part of a visionary curriculum in design

It is beneficial for all when the interests of students, industry representatives, and global experts unite to respect cultural design codes and the symbolic meaning of signs of foreign cultures. European partners from the industry will benefit by educating experts about respecting global design ownership and design heritage. This will entail fair integration and ensure the preservation of human capital. It is necessary for academic institutions to educate and integrate future experts at a very early stage, by implementing cross-cultural co-designing projects as part of the curricula. Implementing this could mean building co-design spaces from kindergarten on, and educating citizens about cultural appreciation and tolerance for design ownership. These kinds of cross-cultural projects and unification, in combination with the application of the seven instruments as defined, could help solve problems relating to 'cultural appropriation' and the misuse of foreign cultural codes, thus serving SDG 4 and 17. As mentioned in chapter 3.1., social co-designing is becoming an increasingly important area in the design education system. Cultural exchange has the potential to enhance the unique quality of identity, especially for young, educated design experts. Our suggestions seek to achieve the setting of new standards regarding the resilient cultural education of all partners.

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PRIMING CULTURE DIFFERENCES IN A CREATIVE DESIGN COURSE: THE INFLUENCE OF DIGITAL STIMULI

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ABSTRACT
Extensive research has focused on the influence of culture on individuals' performance in design, with either positive or negative effects. Moreover, studies have shown that it is possible to prime individuals' cultural values to influence their behaviours in design. However, to the best of our knowledge, no study has explored priming culture in design, especially with digital stimuli. Therefore, we conducted a pilot study to explore the influence of priming culture by digital stimuli in design. First, we created video-based digital stimuli to prime individuals' individualism versus collectivism (IC) cultural values. We tested the digital stimuli in an ideation exercise during a creative design course that aimed to explore and implement essential creative problem-solving and design thinking methodologies in practice for students. The results showed that the collectivism digital stimulus increased the participants' IC value. However, in the other two conditions, the participants' IC values also increased, which was unexpected. Therefore, we discussed the role that enjoyable group ideation plays in participants' IC values. Furthermore, we found that their design aim changes by priming IC values. These findings can support the development of educational practices aimed at encouraging design novices in teams independently of their culture and inspire researchers to further explore the influence of priming culture in design.

Keywords: Digital stimulus, priming cultural differences, creative design, individualism, collectivism

1 INTRODUCTION
Previous research has demonstrated that culture affects design [1, 2], such as individuals' performance and experience during design [3, 4]. We follow Hofstede's definition of culture, in which culture is "*the collective programming of the mind that distinguishes the members of one group or category of people from another*" [5, p. 9]. This definition is further categorized into six dimensions: power distance (PD), uncertainty avoidance (UA), individualism versus collectivism (IC), masculinity versus femininity (MF), long-term versus short-term orientation (LSO), and indulgence versus restraint (IR). On the one hand, culture positively affects individuals' performance in design, such as in people with a higher IC value who generate more original ideas or perform better in group work [6, 7]. On the other hand, culture negatively affects individuals' performance. For example, individuals with a higher PD value are less likely to express their true thoughts and feelings, resulting in a restrained collaboration with their team members, because of their views on the hierarchy between superiors and subordinates [5, 8]. Moreover, cultural values can be primed [9], and previous studies have investigated the influence of priming culture on individuals' cognitions and reactions [10]. However, no study has investigated priming culture in design teams. Considering the increasing internationalization of design programmes and design agencies around the world, it is important to understand how potentially negative cultural influences can be mitigated in design work. Thus, we aim to investigate *how we can prime cultural values* and *the influence of priming cultural values on design* to support novice design work.

2 PRIMING INDIVIDUALISM VERSUS COLLECTIVISM
Priming is a widely used research approach for understanding how performance or behavior can be unconsciously affected by a stimulus [9, 11]. Regarding priming culture dimensions in particular,

several studies have demonstrated the effectiveness of textual stimuli in priming IC [10, 12, 13]. IC, as one of the cultural dimensions, refers to the degree to which people in a society are integrated into groups [5, 11]. People who score low in IC are considered individualists with loose ties to the community, who care mostly about themselves and their immediate family. Conversely, people with a higher score of IC, as collectivists, cultivate solid and cohesive ties between groups, such as in the society or country they belong to [5]. Previous studies have verified that IC value had the most considerable effect on individuals' performance in design, such as the number of ideas and sketches in ideation [14]. Therefore, as one of the first studies priming culture in design, our study only focuses on IC value. For priming IC, one of the most popular priming stimuli used in past studies is considered to be the story of Sostoras [10, 12, 13], "*(…) a warrior in ancient Sumer, [who] was largely responsible for the success of Sargon I in conquering all of Mesopotamia. As a result, he was rewarded with a small kingdom of his own to rule. About 10 years later, Sargon I was conscripting warriors for a new war…*" [13, p. 652]. Sostoras has to decide who to put in command of a detachment of soldiers to aid the king, and as such, participants are exposed to different content, depending on the condition they are in. On the individualism condition, Sostoras nominated a "…*talented general. This appointment had several advantages. Sostoras was able to make an excellent general indebted to him…*" [13, p. 652], while also increasing Sostoras' own prestige. In the collectivism condition, participants received a different story in which Sostoras nominated a family member, which benefits their family and increases loyalty among them ("*This appointment had several advantages. Sostoras was able to show his loyalty to his family…*") [13, p. 652]. Particularly in Gardner, Gabriel, and Lee's study [10], these priming stimuli triggered participants to demonstrate collectivist and individualist behavior in the corresponding collectivism and individualism conditions. As such, one's sense of IC is malleable within the constraints of one's culture.

With the development of technology, it is possible to adopt digital stimuli (e.g., videos) for priming cultural differences, more vividly and immersive [15]. However, it is still unclear how such approaches influence creative design work in relation to culture. Thus, we add one more component to our research aim: *to investigate the influence of digital stimuli on priming cultural values (the IC dimension)* and to understand the *influence of priming culture on novice design work*.

3 PILOT STUDY

3.1 Digital stimulus design

To design the digital stimuli, we used the story of Sostoras [10, 12, 13]. We built it with the game engine Unity 3D, which offers code in C #, and the required items for the design could be purchased from the Unity Asset Store [16]. In presenting the story, we divided it into three views, starting with the background of the story, with a 360-degree view of the environment with a fixed interface in front to show the background of the story in 75 seconds, as shown in Figure 1 (a). Then, the camera stops in front of the building and starts to introduce the king (15 seconds), as illustrated in Figure 1(b). Afterwards, the camera moves to the king's view to tell the story in 90 seconds (Figure 1 (c)) into three branches as three single conditions. The individualism condition branch was designed to prime a lower IC value (i.e., trigger individualistic goals), where the dialogue shows that Sostoras decides to choose a talented general, Tiglath, which benefits him. The collectivism condition branch was meant to prime a higher IC value (i.e., trigger collectivistic goals). There, Sostoras decides to choose his brother, also named Tiglath, which brings unity and prestige to the whole family. For the neutral branch as a control group, Sostoras also chooses the general, Tiglath, without explaining any reason, resulting in no cultural priming in the neutral condition as a control group.

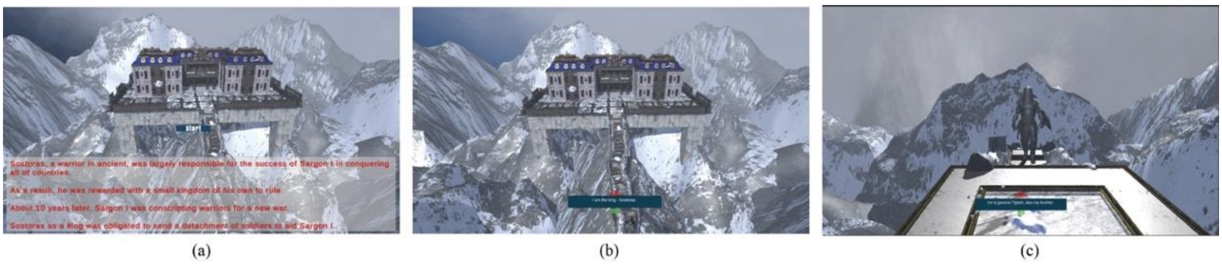


Figure 1. Screenshots of the digital stimuli

To design the scenes, we used the keywords "ancient Sumer", "a small kingdom" and "a new war." This resulted in a scene that transpired in an ancient and tense atmosphere because of the coming war, with an imperial palace in the background, as shown in Figure 1 (a and b). Moreover, we excluded a few keywords, such as "Mesopotamia," because our participants were from different countries and might have specific feelings about this historical location. In addition, to create a tense atmosphere of impending war and to avoid potential biases, the characters were dressed in military uniforms that covered their faces and skin, hiding their race and geographic characteristics. The background audio is intense to match the story, purchased from Unity Asset Store.

3.2 Study set up

We applied the digital stimuli in an exercise during a creative design course, a seven-week class that aims to understand and implement essential creative problem-solving and design thinking methodologies in practice. Before the first week of the course, we asked the participants to complete a questionnaire to obtain their initial cultural values used to compare the difference between pre- and post-digital stimuli, which was developed by Yoo et al. based on Hofstede's cultural dimensions with acceptable reliability and validity [17]. In the sixth week, participants were randomly divided into one of three subsequent days (the first day for the neutral condition, the second day for the individualism condition, and the third day for the collectivism condition), as a between-subjects study. The corresponding digital stimuli were integrated into each condition before the group ideation exercise (two or three participants in a group). We asked them to complete a questionnaire to collect their IC values (to compare them with the previous questionnaire's results) [17] after the exercise. Although 46 participants participated in the exercise, we only included data from 22 participants (21 participants did not complete both the pre- and post-questionnaire, while three participants were excluded during the analysis because their data were outliers). The 22 participants were master's or doctoral students from different majors (e.g., mechanical engineering). The mean age of the 21 participants was 24.24 years, with a standard deviation of 2.17 years (one participant preferred not to say). In addition, 9.1% of the participants were female, and 86.4% were male (one participant preferred not to say). Thirteen of the participants were from Finland, two were from Italy, two from Indonesia, and one participant each from China, Iran, Sri Lanka, Pakistan, and Vietnam. The number of participants in the three conditions was six (neutral condition), seven (collectivism condition), and nine (individualism condition). The exercise consisted of the following seven steps, using collaborative sketching (C-Sketch) [4]. The only difference between the three conditions was the digital stimuli.

1. The participants were introduced to the C-Sketch and task: "Generate as many ideas as possible for a means of transport for the mountain area" (Figure 2(a)).
2. Different versions of the video were presented with the digital stimulus (the participants were not told about the aims of the study or stimuli) (Figure 2(b)).
3. Participants were asked to ideate individually by generating as many ideas as possible via sketching and annotation (Figure 2(c)).
4. During group ideation, participants were encouraged to edit, elaborate, and add more ideas, based on each other's sketches and notes (Figure 2(d)).
5. During group discussions, participants could ask and answer questions about the other group members' contributions (Figure 2(e)).
6. Finally, participants had to select and develop their best ideas (Figure 2(f)).
7. The participants filled in a questionnaire about their cultural individualism–collectivism views [17] by scanning the code, as shown in Figure 2(g).

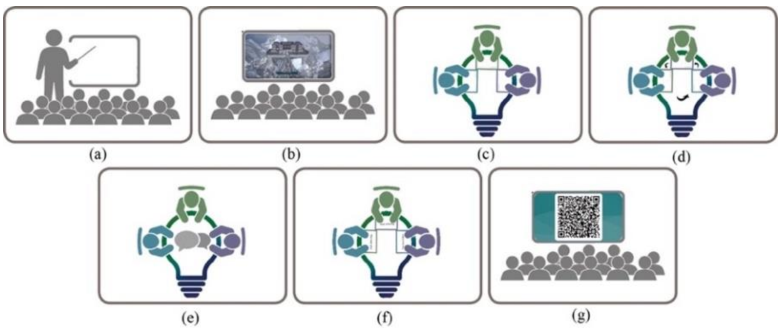


Figure 2. Exercise procedure

4 RESULTS

To analyse the effectiveness of the digital stimuli in priming IC values, we extracted the difference between the two individuals' cultural value questionnaires; then, we ran the Shapiro–Wilk test, which showed that our data was not normally distributed, and there were outliers in the data. Therefore, we deleted the outliers and tested our data with nonparametric tests.

Although all conditions showed an increased mean of IC values difference score between the pre- and post-questionnaire (Figure 3 (a)), only the collectivism condition had a statistical difference $z = 3.22$, $p = .001$, tested by related-samples Wilcoxon signed-rank test. A Mann–Whitney U test was used to determine if there were differences in the difference scores between the three conditions. The mean difference score was statistically significantly higher in the collectivism condition (2.57) than in the neutral condition (0.5), $U = 4.5$, $z = -2.411$, $p = .016$, and in the individualism condition (mean = 0.33), $U = 5.5$, $z = -2.806$, $p < .005$.

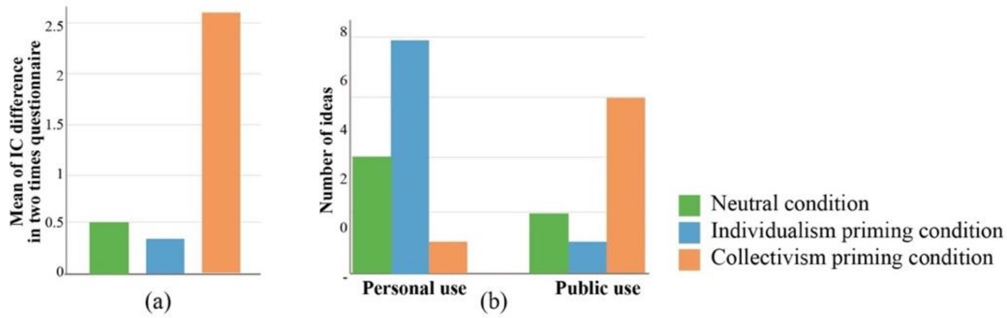
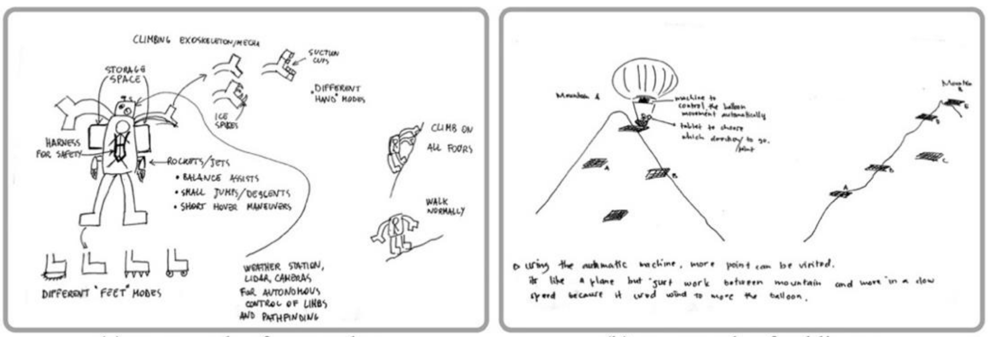


Figure 3. Comparison of the three conditions

Considering the goal of the ideation task (to generate ideas for a means of transport for the mountain area), the participants' output could be divided into two categories of design aims: transportation for personal use (e.g., a wearable small aircraft, Figure 4 (a)) or public use (e.g., a hot air balloon with stations, Figure 4 (b)). We ran a Mann–Whitney U test, and the design aim was statistically significantly different in the collectivism and individualism conditions, $U = 8$, $z = -2.899$, $p = .012$. As such, participants in the collectivism condition generated more ideas (6) for public use than for personal use (1), while the individualism condition led the participants to generate more ideas (8) for personal use than ideas (1) for public use (Figure 3 (b)).



(a) an example of personal use (b) an example of public use

Figure 4. Examples of outputs for different design aims

5 DISCUSSION AND LIMITATIONS

The IC value of the collectivism condition increased with statistical significance, as we could expect based on previous literature [13], which confirmed the effectiveness of the digital stimuli in influencing the score of IC cultural dimension. As such, participants in this condition became more focused on the "we," rather than the "I" [10], which also influenced the ideas generated. The individualism and neutral conditions seemed to have marginally increased their IC value to become collectivistic-oriented, which is unexpected considering previous studies [10, 12]. Nevertheless, there was no statistical difference, meaning that the neutral and individualism conditions did not significantly trigger a change in the participants' IC values. By looking more carefully into the participants' course documentation, which they had to upload weekly, we could infer that the method (C-Sketch) and process we applied in the exercise could possibly have influenced the participants' IC values in the neutral and individualism conditions. One participant with an increased IC value (from the individualism condition) said: *"Working with the Collaborative Sketching method felt very natural, because it feels almost like working alone while keeping the advantages of working in a team. By cutting out discussions and confrontation, you can focus on creativity and only at the end evaluate the idea each one has come up with and discuss them*". Another participant also expressed: "*I really liked the ideas generated by my peers and had a lot of fun adding my own upgrades into their designs".* Therefore, it could be that the pleasant experience in group ideation may have triggered the participants to think with the "group" in mind, which might explain the slight increase in IC value in the neutral and individualism conditions. Nevertheless, these insights cannot be confirmed with our data.

Another finding in our study was that the stimuli influenced the participants' outputs (design aims). When the participants developed their final and best ideas, most of them portrayed public transportation solutions in the collectivism condition, while the participants in the individualism condition developed more ideas meant for personal transportation, such as for one person. Although numerous studies have explored the use of stimuli and the influence of these stimuli in design [18, 19], stimuli priming culture in design is a little-discussed topic. Our study shows evidence of the impact that digital stimuli can have on cultural dimensions and design (i.e., design aims). As such, it presents an opportunity to explore how cultural dimensions can be malleable to influence novice designers in their design.

Several limitations should be considered. First, the small number of participants might limit the generalizability of the results. Second, the unbalanced number of participants in three conditions (e.g., the neutral condition had only six participants) might have influenced the results compared with other conditions (seven in the collectivism condition and nine in the individual condition). Third, we tested the digital stimuli in a class without strict experimental procedures and controls, which may have influenced the results. These are aspects to take into consideration for our future studies.

6 CONCLUSIONS AND FUTURE WORK

We designed digital stimuli as videos for priming cultural differences, specifically the IC dimension, during an exercise in a university creative design course. Our results show that the collectivism stimulus effectively primed individuals' IC value, resulting in a higher IC value than in the neutral and individualism conditions. This means that individuals' cultural values can be primed by digital stimuli. Furthermore, we found that, by priming participants' IC values, their design aims differed based on the corresponding digital stimuli. Participants in the individualism condition developed more transportation solutions for personal use, while participants in the collectivism condition created more ideas for public transportation. In addition, we discussed the possible influence of the group ideation method (C-Sketch), which might have positively influenced the participants' experience of group ideation and caused a slight increase in their IC values. These insights reveal potential benefits for design and engineering education, as it often involves a significant amount of collaborative work, which may pose a challenge for novices who have more individualistic behaviours. One potential approach is to foster collectivist values within groups, which may facilitate greater collaboration (e.g., mitigating the negative influence of individualism in collaborative ideation of one conversation at a time [20]) among students and encourage them to prioritize collective goals over individualistic perspectives. In addition, it is possible to promote individualism during the ideation process, with the aim of motivating individuals to generate a greater number of ideas [14]. Conversely, collectivism can be emphasized during the idea selection phase, in order to achieve an objective consensus [20]. As more and more design schools increase their internationalization, it is important to consider the impact of culture on how we teach design and prepare our students to ideate without creative constraints, such as those implicitly imposed by culture.

Our study might serve as the groundwork for further exploration of digital stimuli from a cultural perspective in engineering and design education, and creativity research. In future studies, we aim to improve the digital stimuli to provide an immersive experience with virtual reality (VR) equipment for participants and investigate whether a digital stimulus supported by VR could prime individuals' cultural values, thus affecting their performance in ideation and design creativity.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7-8 SEPTEMBER 2023, ELISAVA UNIVERSITY SCHOOL OF DESIGN AND ENGINEERING, BARCELONA, SPAIN

COMBATTING LONELINESS BY INTRODUCING A START-UP PROJECT FOR FIRST-YEAR STUDENTS

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ABSTRACT
Loneliness among university students is a major issue. For new students, the first week at the university is crucial to develop a new social network and possibly reducing loneliness. This study aimed to investigate the effect of having a group project for new university students in the start-up week of the first semester. The social aspects were the focus of this study, however, also the students' reception of the project task is investigated. The students were working in groups of 4–5 students and were asked to design a small student cottage. To investigate the effects of having a group project at the beginning of the first semester, a survey was distributed at the end of the first week The results indicated several benefits both academically and socially. 88% rated the project *to a high degree* and *to a very high degree* contributed to academic collaboration. Furthermore, when asked to which extent the project encouraged a social arena and contributed to gaining new friends, 90% and 79% respectively, replied either *to a high degree* or *to a very high degree*. The results of this study can provide other educational institutions with insights on how to meet first-year students, and how to provide a social arena. By having a Start-up project which is both a theoretical and physical task, the students find other students to befriend and work with.

Keywords: Student environment, start-up project, civil engineering, education, survey

1 INTRODUCTION
The first year of a students' higher education considerably affects their performance and probability of completion. Even the first weeks are a crucial phase [1]. It has been found that social adjustments during the first weeks are related to a higher probability of completing a degree [2]. Findings by Wilcox et al. [3] suggested that social support networks have a major influence on preventing dropout and that not making new friends was of high importance when deciding whether to continue or not. During the first weeks, it is an urgent need for social arenas to interact with others [3].
Every four years the SHoT study (*Students' Health and Wellbeing Study*) is carried out to map the health, well-being and psychosocial environment of students in Higher Education in Norway [4]. In recent years there has been an increase in reported loneliness among students. In SHoT 2022 [5] 36% reported that they either miss someone to be with, feel left outside or feel isolated often or very often. This is an increase from 2018 [6] when 30% of the students reported this. Another result from this research is that 34% report that they only have a few friends and 7% report that they do not have any friends. Loneliness amongst university students is reckoned a major public health issue [4]. These students are vulnerable to feeling loneliness, as most of them are in a stage of life where they are transitioning from teenagers to young adults [4]. This period in life is associated with moving away from home and moving to a new place, and a need to develop new friends and social networks.
The first week (*introductory week*, *Fadderuke* in Norwegian) at university is in Norway often associated with non-academic social activities and partying. In Norway, 77% reported that they participated in the *introductory week*. It was shown that 8 out of 10 felt that it was expected to drink alcohol during the *introductory week* [7]. It has also been found that 61% of the students want more events without alcohol and many feel that there is too much drinking in the student environment [5].
Based on the findings above, it is imperative to integrate students into their new academic environment as effectively as possible, meaning that universities must be aware and utilize this window of opportunity to give students a meaningful start. The purpose of this study was to investigate the effect of having a

group project (Start-up project) in the first week for first-year students, as a supplementary activity to the other *introductory week* activities.

2 CASES

The students participating in this study were first-year civil engineering students at the bachelor and master level at the University of Agder (UiA), Norway. The students were assigned a Start-up project in their first week at the university. The Start-up project was developed by lecturers in the Civil Engineering department and supervised by the study program leaders. The project was presented to the students as a design project and not a get-to-know-each-other project. The goal of the project was to design a small student cottage, with the main assessment criteria being functionality, creativity, sustainability, and design. The long-term goal of the project is to build an actual cottage for the students to use. They also had to build a model on a scale of 1:20. The students were divided into groups of 4–5 students and had three days to complete the project. They started their study on August 15th and was given the information about the assignment on the 16th of August.

The students were working on their models of the cottage on Thursday the 18th of August. In the evening of the same day the study program leaders hosted a barbeque for all the first-year students. The purpose of this barbeque was to incentivise the students to complete a full day of working with the project, and to facilitate a non-alcoholic social arena. On the final day (19th of August), they presented their project in front of the rest of their class, and a jury consisting of employees from the civil engineering department. Each project was evaluated by the jury according to the aforementioned criteria, and the winner were awarded sweaters from the Civil Engineering department. The students were informed that the project was not mandatory, but participation was highly recommended.

3 METHODS

The purpose of this study is to map the students' experiences from completing a start-up project. The students participating in the Start-up project were asked to answer a survey immediately after the presentation of the final projects. The same survey was sent to both bachelor and master students. Table 1 shows the number of students answering the survey and response rate. The survey consisted of 11 multiple-choice questions and two free-text options to give more detailed comments. All surveys were distributed through the Learning Platform *Canvas* and made with SurveyXact.

The students were asked to evaluate the different aspects of the Start-up project on a scale from 1 to 5, where 1 meant *to a very low degree* and 5 meant *to a very high degree*. The survey questions covered social aspects, study environment, motivation, and academic benefit. However, the main aim of this study was to investigate the social aspects of having a project at the beginning of the first semester.

Table 1. Data about the surveys

	Distributed	Total number of students	Number of respondents	Response rate
Bachelor students	Aug 19th 2022	79	53	67%
Master students	Aug 19th 2022	20	17	85%

4 RESULTS AND DISCUSSION

4.1 Social aspects and study environment

Figure 1 shows the results related to the outcomes of working in a group during the Start-up project. The students reported that working in a group generated many positive outcomes.

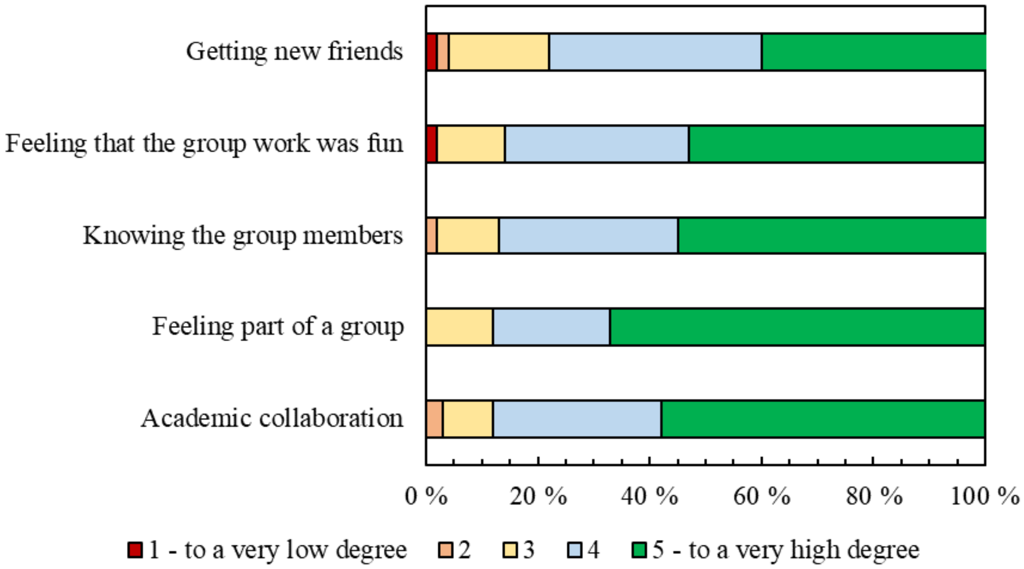

Figure 1. Response to the questions "To what degree did working in a group contribute to"

Most students reported that the group work contributed to a *high* or *very high degree* of getting new friends (88%), feeling part of a group (88%) and getting to know the group members (88%). When 88% of the students' experience getting new friends during this Start-up project it can result in a reduction of the experienced loneliness that was demonstrated in the SHoT study [5]. We wanted to avoid a completely theoretical assignment and give the students a task where they had to build a physical model. This was done to encourage the students to not only meet their peers physically, but also to meet on campus, to possibly increase the sense of belonging. Like a virtuous circle, the students will have some familiar faces when arriving at campus, increasing the likeliness of getting to know more of their classmates, reducing the feeling of loneliness, and being included in an academic collaboration. Also, the barbecue allowed the students to meet the university staff in an informal environment. This may lower the threshold for some students later when they need to interact with the university staff. According to Pedler et al. [8], students with a greater sense of belonging usually have more academic self-confidence, higher motivation, higher achievements and higher academic engagement. Additionally, a sense of belonging and social integration is essential for retention [3].

The feedback from the students in the free-text option of the survey was that the group work was a fun and social activity, with little pressure. However, a small number of participants reported that it *to a very low degree* contributed to getting new friends (2%). Some students also reported issues with few group members showing up for the group work and that these did not contribute to solving the assignment.

Figure 2 differentiates the answers to questions regarding working in groups between bachelor and master students, showing the percentage answering *to a high* or *very high degree*. There is a clear positive response to the group work, both academic collaboration and pure social aspects. For the master students, all students (100%) answered that the group work contributed *to a high* or *very high degree* of getting to know the group members, feeling part of a group and academic collaboration.

Previously there has been little focus on having a Start-up project at the beginning of the master studies at UiA. Although most of the master students have completed their bachelor's degree at UiA, a clear majority of the master students stated that this Start-up project gave them new friends. However, we wanted to integrate the students coming from other universities and chose to run the same start-up project for everyone. The results of this study show the importance of having a Start-up project for the master students as well as the bachelor students.

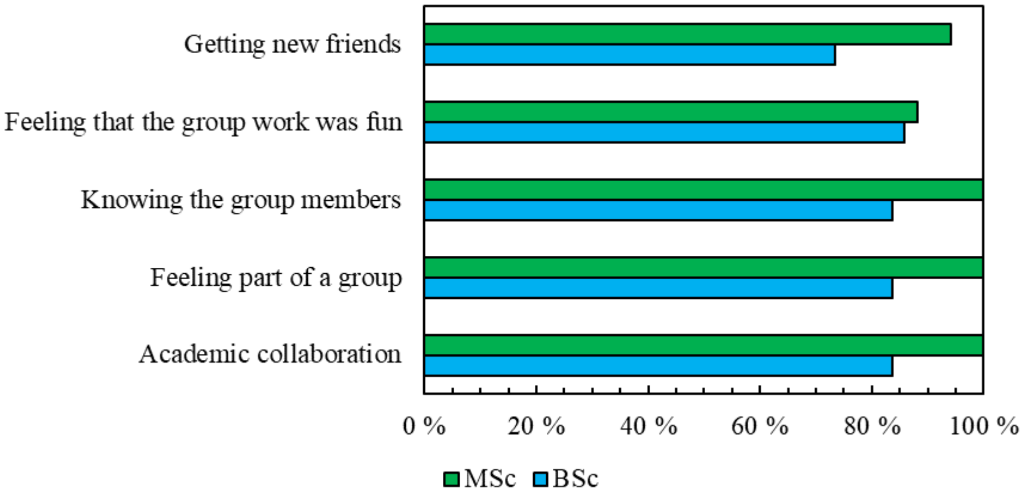

Figure 2. Percentage answering "to a high and very high degree" on the questions in Figure 1. The figure differentiates between bachelor (BSc) and master students (MSc)

In Figure 2 it is also clear that the master students scored every aspect higher than the bachelor students. The reason for this is not investigated in this study but may be explained by their previous educational experience. The importance of cooperation during the study period might be more obvious for the master students since they have already finished at least three years of higher education.

4.2 Academic aspects

Figure 3 shows the students' experience of the task for the group project. The figure illustrates that few students felt that the task was stressful and unnecessary, while most students experienced *to a high* or *very high degree* that the task itself was fun (89%) and relevant to the study (71%). However, only 57% of students experienced *to a high* or *very high degree* that the task was educational.

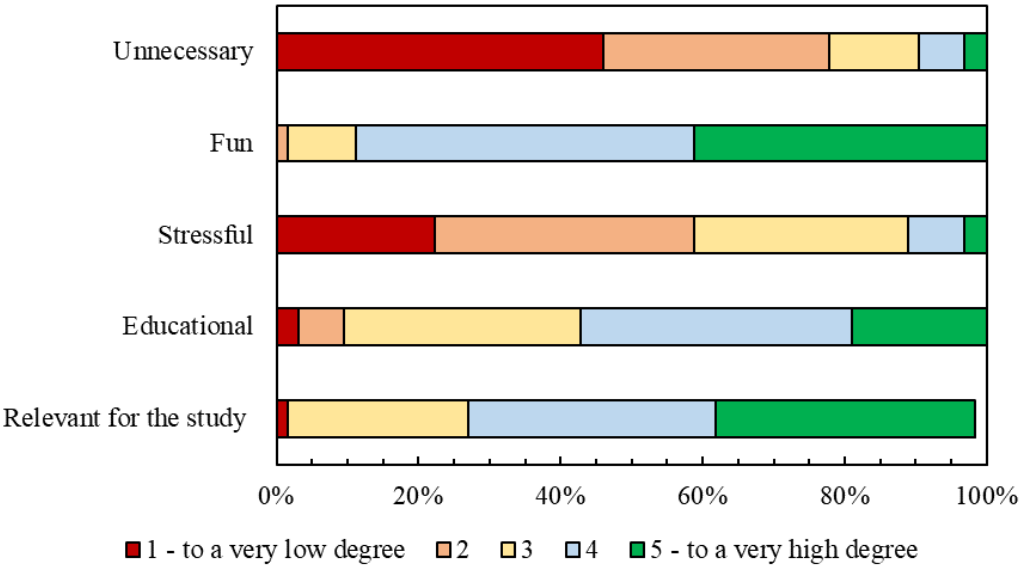

Figure 3. Response to the questions concerning to what degree the project task was

Although the focus of the Start-up project was to be a social arena, a high educational outcome was also desirable. The students starting at the Civil Engineering education at UiA have various backgrounds. A possible explanation for the relatively low reported educational relevance might be that it was desirable to include all the students in the Start-up project. Therefore, the Start-up project did not require any prior knowledge.

Figure 4 shows that there was little difference between the bachelor and master students' perception of the project task. The largest differences can be seen regarding how relevant the task was for the study/

academic field. Almost similar tasks were given to both bachelor and master students. Hence, to make it more relevant for master students a more specialised project could be made. In contrast to the bachelor students, the master students have some prior knowledge. Hence, the Start-up project for the master students could be made more relevant for the study which again could increase the educational outcome. Intriguingly, both the bachelor and master students found the Start-up project to be fun, making it a viable option to the *introduction week*. This could reduce the pressure of drinking alcohol [7] and accommodate the request of more events without alcohol [5].

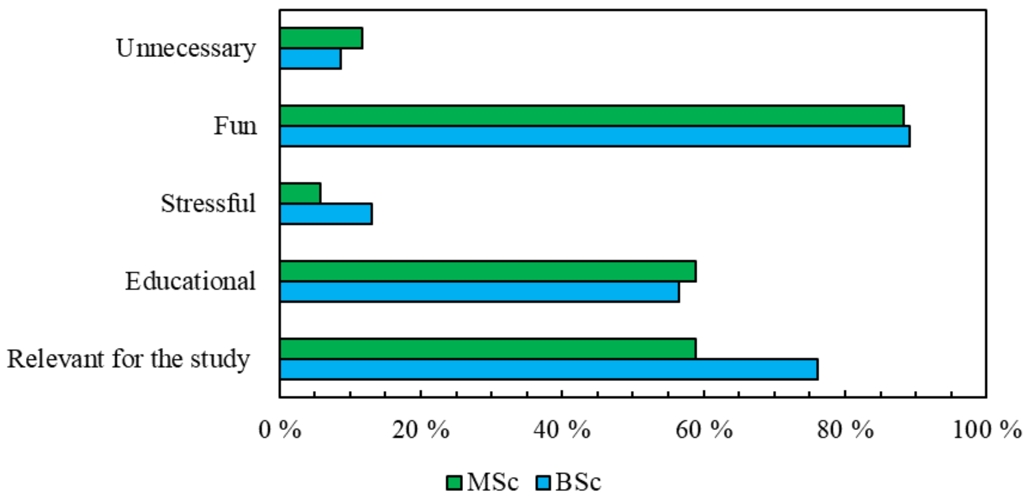

Figure 4. Percentage answering "to a high and very high degree" on the questions in Figure 3. The figure differentiates between bachelor (BSc) and master students (MSc)

Overall, these results indicate that a Start-up project can be beneficial for social integration and introduce new students to the academic field. Whether or not initiatives at the beginning of the degree contribute to minimising loneliness should be further assessed at several time points. According to Bowman [1], the effect of various initiatives to predict the well-being and belonging of university students should be assessed over time and not only at one or two time points.

5 CONCLUSIONS

This paper set out to investigate the effects of having a group project for new bachelor and master students in the start-up week of the first semester. Based on the knowledge obtained in this study, the following conclusions can be drawn:

- The Start-up project was found to give the students an introduction to the academic field.
- Working in groups had multiple positive outcomes, e.g., the students got to know the other students, and made new friends.
- Few differences were found between bachelor and master students, both concerning the social aspects and perception of the project task.
- Although the focus of the group project was to facilitate a social arena, an effort can be made to develop project tasks that also give a higher educational benefit.
- The project can also be an alternative arena to make new friends and work with a project related to the academic field, as well as being a non-alcohol activity.

The research presented is based on one attempt to make a simple Start-up project aiming at contributing to social and academic integration. However, the results are limited to short time effects, long-term effects have not been covered in the present study. The findings might offer insight into how to meet new students and a possible approach on how to facilitate an academic and social arena for new students.

6 FURTHER RESEARCH

A further study should assess the long-term effects of the Start-up project and investigate whether such initiatives can reduce the loneliness of university students as well as investigate if it can contribute to student retention. Since many of the master students know each other from previous years a different kind of start-up project could be considered.

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REFRAMING FROM FUTURE TO PRESENT IN INDUSTRIAL DESIGN

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ABSTRACT
Design fiction supports the development of tangible prototypes to assess factors in a near future in a more concrete way. The feedback loop into the present, however, remains as a set of recommendations or guidelines for new product development. This paper describes a methodology that includes reframing specific factors from the future to the present by using two related problem formulations, one in the future and one in the present. The methodology is used in an MSc of Industrial Design course where student teams work on project formulations for Space settings in a near future and reframe the projects to situations on Earth where factors concerning the problem, context, users or working principles are revisited, interpreted and reworked to create a value proposition for the present in a concrete manner.
The findings indicate that insights can be interpreted at various levels of abstraction and, when combined with critical thinking, stimulate the reuse of processual aspects and reframing of specific factors addressed in the future formulation into the current project formulation.

Keywords: Reframing, wicked problems, industrial design, design fiction, future forecasting

1 INTRODUCTION
Industrial design always involves a degree of future forecasting since product development requires understanding and testing various factors of the context in which the product will be used. User-centred design methods enable anticipating and testing user needs, prototyping supports the iterative development of working principles, and engagement with relevant stakeholders support the creation of a coherent value proposition. One can argue that these design methods of traditional problem-solving address short and medium-term forecasting because under such framework, technological development or new user needs will be addressed through a new cycle of product development.
Methods for longer-term forecasting that encompass designing tangible outcomes includes speculative design [1] and design fiction [2]. Speculative design uses storytelling and design outcomes as prompts for building a tangible scenario in a potential future. The potential future is then critically reflected upon by addressing values, ethics and implications that lead to the formation of new perspectives. Design fiction shares the common ground of being critical towards the future. The tangible prototypes are also used as means to represent factors related to technology and culture in a potential future to spark discussion about the consequences of decision making. The focus is deeper on existing archetypes [2, p.87] which are ordinary artifacts of daily life. When compared to speculative design prototypes, design fiction prototypes are often less uncanny, and therefore more relatable. Therefore, such prototypes of design fiction focus away from storytelling and remain more closely related to prototypes used as prompts for immediate reflection on the implications for users, interaction within the envisaged context together with people and other systems. For this reason, I position design fiction prototypes as having a function in the design process that is closer to traditional prototypes used in industrial design.
The feedback loop into present product development is one of the most important aspects of producing tangible artifacts as probes into possible futures. Design fiction [2, pp. 194–209] proposes disseminating the results of critical thinking in form of recommendations that will impact strategy. This feedback loop affects organisations and product development from top-down, which is similar to the recommendations proposed by future foresight [3]. I hypothesise that if the use of prototypes enables a better understanding of the envisaged future, then, the feedback loop into the present might also include the development of tangible outcomes. To fulfil this premise, a degree of relationship between the envisaged future and the

present situation must be established. Accordingly, experiments, insights, sensemaking and frames [4] used to tackle the future may become a baseline to assess the present situation.
The main goal of the methodology presented in this paper is to test this hypothesis in an educational setting, and it unfolds as follows: 1) Proposing a hypothetical situation in the future as a way to probe on factors affecting present situations; 2) Addressing the future situation by designing a tangible outcome to critically reflect upon its implications; 3) Reflect-in- and through-action is applied to propose a second-order tangible outcome to address the present situation. Steps 1 and 2 are addressed using traditional industrial design methods and design fiction, and step 3 through reframing.
Reframing occurs in teams with different patterns from individual reflection-in-action [5], where team members "engage in if-then arguments, and some of the experiments interact with the prototype, to assess particular situations". Team members then create new frames based on the reflections and proceed on to redefine the problem and design a solution. Reframing in the present paper is based on the stages defined by Stompt and co-authors [5] and requires assessing corresponding problem formulations at a high abstraction level and linking relevant product functions to develop operational solutions for contexts sharing similar requirements.
This paper describes how the methodology was applied in a project module in an MSc in Industrial Design, in which students chose a living function and designed products to support human activities in future settlements in space (Moon or Mars). Secondly, they developed concepts to improve existing situations on Earth that shared certain requirements with the first solution. The analysis of the projects developed by students focuses on specific factors, in both Space and Earth project proposals. The assessment of what factors were maintained, reframed, or abandoned supports the reflection about the methodology. The paper discusses the application of the methodology in academia and design practice after an assessment of its potentials and shortcomings.

2 METHOD

The project formulation presented in this paper was part of a revision of a 20 ECTS course for students in the MSc in Industrial Design at Aalborg University. The learning objectives were already established and were not changed. Overall, the competencies that students must accomplish by the end of the course focus on the topic "technology innovation driven by design" which entails transforming technology opportunities into strategies, concepts and specific product proposals through integrated product development. This topic was interpreted as a potential to explore the interrelationships between science, engineering, and design as defined in Oxman's krebs of creativity cycle [6], by emphasizing design as the catalyst to addressing technological advancements in both visionary and operational ways. This requires designing products and production systems in tandem, working with limited infrastructure that is currently under R&D and bridging the gap between conceptual design and production.

2.1 Course structure

The course spanned over 12 weeks and included five milestones. The academic evaluation included the submission of a process report, followed by an oral exam that included a presentation and discussion of product proposals and respective design processes. Students worked in teams of four or five elements. Each team was supervised by a main supervisor with a background in industrial design and a technical supervisor with a background in materials and production. In total, four faculty members, two from each background supervised the six teams of students.
The five milestones were defined as follows: 1) Scope and principles; 2) Analysis of concepts; 3) Concept visualization; 4) Details and conclusion for the Space proposal; and 5) Reframing for proposal on Earth. Each student team presented their work and received verbal feedback from the four faculty members and colleagues during the milestones. Milestones were used as learning spaces where concepts were questioned and discussed, and the process was assessed based on the validity of the methods used in relation to the specific factors of the inquiry. Milestones also served as learning spaces for friction and uncertainty, allowing different perspectives to be debated based on the proposed visions, with the goal of constructing, complementing, or reframing the core questions.
The semester was divided as follows: the Space project proposal was developed over eight weeks, with four milestones; the reframing for the Earth concept proposal was developed over two weeks with one milestone. The finalization of submission material took two weeks, with one week of preparation for the exams.

2.2 The assignment

'From Space to Earth' was the semester's theme. The goal was twofold: first, to imagine how new technologies could support activities in human settlements on the Moon or Mars in the near future, and second, to consider how these new applications could be reframed to improve existing situations on Earth. To develop their projects, student teams chose one of the following living functions: 1) Food systems; 2) Clean air and water; 3) Leisure and physical activity; 4) Energy efficiency; and 5) Interior furnishing. All projects should consider transportation, manufacturing, and assembly feasibility.

Students address the intertwined relationship between science and design by developing concepts for the foreseeable future that are based on ongoing research and cutting-edge technology. Second, when reframing the project formulation for Earth, students apply critical thinking to identify a situation that has some degree of commonality with the one developed for Space and develop a concept to address it.

2.3 Limitations

The semester occurred during a Covid-19 lockdown in Spring of 2021. Accordingly, all work was done remotely, including all academic assessments. This limited access to workshops for physical prototyping and face-to-face access to key stakeholders (users, researchers, component suppliers). Remote work enabled, however, a higher level of empathy regarding future communications between Earth–Space.

3 RESULTS

Table 1 provides an overview of the main factors – problem, context, users and working principles – concerning the project formulations. Furthermore, it provides a basis for assessing the degree of alignment between project formulations (Space and Earth), classified as Y (yes), N (no), or P (partial). Based on the established order of factors, the following alignment of project formulations is observed: 1. YNNN; 2. PYYP; 3. YPPP; 4. PNNN; 5. PNNP; 6. YPPP. These strings enable to conclude that reframing in projects 1 and 4 have a lower alignment, medium alignment in project 5, higher in projects 2 and 3 and highest on project 6.

Table 1. Main factors of the project formulations for Space and reframing for Earth

Team #	Factors	Space project formulation	Earth project reframing	Align.
1	*Problem*	Food production (Moon)	Food production	Y
	Context	Farming site	Home	N
	Users	Community	Family	N
	Working principles	Modular, self-supporting structures	Wall-mounted individual vases	N
2	*Problem*	Wastewater disposal (Mars)	Solid waste disposal	P
	Context	Living pod to habitat structure	Apartment in high-rise building	Y
	Users	Inhabitants	Inhabitants	Y
	Working principles	Electromagnetic rail system, bag, valves	Electromagnetic rail system, plastic bin, fork frames	P
3	*Problem*	Circadian rhythm monitoring (Mars)	Circadian rhythm monitoring	Y
	Context	Living unit	General use	P
	Users	General	Specific / Blind	P
	Working principles	Wearable device, glasses, light sensors	Wearable device, wristwatch, temperature sensors	P
4	*Problem*	Water capturing and transport (Moon)	Water capturing	P
	Context	Extract site to treatment facility	Rooftops in vulnerable housing areas	N
	Users	Automated system	Citizens	N
	Working principles	Electromagnetic rail system, carbon fibre track, 3D printed metal	Plastic water tank, in-situ materials	N
5	*Problem*	Physical activity and mental health / gamification (Mars)	Learning and physical activity / gamification	P
	Context	Living unit	Primary schools	N

	Users	Astronauts	Children	N
	Working principles	AR lenses, vibration board, sound waves, interconnected computer networks	Touch board, lights, interconnected computer networks	P
6	*Problem*	Food production (Mars)	Food production	Y
	Context	Living units / scalable	Family housing in refugee camp / scalable	Y
	Users	Community / astronauts	Community / refugees	Y
	Working principles	Cradle-to-cradle, tarpaulin, ceiling-mounted structures	Cradle-to-cradle, tarpaulin, self-supported structures	P

3.1 Low alignment: one factor addressed or partially addressed

In project 1, only the problem of food production is addressed in both formulations. Despite this fact, the team stated that "research done during the Moon scenario was useful to determine the technologies [hydroponics] used in this new [Earth/home] scenario".

In project 4, the water capturing problem was partially addressed, a correspondence that was established only at a higher level of abstraction. "Something both proposals have in common is their ability to take advantage of the environment, which shares the same overall problem: accessibility to water. The impact of context in both cases had a major influence on the concept development. (…) It was difficult to find a way to reframe the product to Earth because the technologies used [for the Moon proposal] would not work in the environment on Earth, and transportation of water on Earth is not calling for a solution."

3.2 Medium alignment: two factors partially addressed

Project 5 addresses similar problems by using similar working principles in both proposals. "The project focuses on motivation to exercise the vestibular system as part of the obligatory training [on Mars]. This project not only accommodates an exercise tool but also boosts mental and physical health by making the training fun in a social community setting. (…) The approach of motivation and physical activity benefits the brain and will be used for reframing new learning experiences in primary schools. (…) The strategy for reframing incorporated key elements from the original product. Hereby the reframing centred around a holistic approach to motivating someone (…) through gamification. At the same time the active element, aesthetics and interaction were kept as a part of the concept."

3.3 High alignment: all factors fully or partially addressed

In project 3 both proposals address the problem of biomonitoring the circadian rhythm of users. The Mars proposal is a system encompassing circadian light glasses, a monitoring device, and a charging station. The glasses simulate "a regular day with the right light intensity and colour hue" to enable the daily levels of hormone production. Reframing focused on finding users on Earth that shared similar challenges of circadian rhythm due to no perception of light. "Circadian rhythm also can be manipulated through temperature. This is the working principle of [the product for Earth. It] allows blind people to reach a similar optimized perception of the day, by regulating through changes in body temperature, and providing them with an aid that can help them keep track of time during the day. This is all controlled by the watch."

Project 2 partially aligns problem and working principles and fully aligns context and users. "The strategy of reframing [from Space] to Earth started with an identification of [the Space proposal's] strongest and most innovative competencies and clarifying them. An investigation on latent problems on Earth was explored to find further possibilities suited to related aspects of [the Space proposal]. This both contained the field of similar situations, features, or related problem areas, such as transportation, containing and handling of substances."

Project 6 fully addresses the same problem formulation, context and users when analysed from a high abstraction perspective. These factors, however, could be characterised as partial if analysed in more detail. The self-sufficient food production problem for Mars further encompasses the creation of glucose as a source for bioplastic that would, in time, be used as building material to scale up the system. Such conceptualisation is not present in Earth reframing. The "reframed product proposal [is] developed on basis of some of the same principles and knowledge. (…) Common to both proposals is the focus on a temporary plant growing solution with minimum environmental impact, and the use of locally available resources."

A cradle-to-cradle approach was considered in both formulations. However, in the Earth formulation, for refugee camps, the tarpaulin used is refurbished from existing tents, thus applying a different circularity level. This process is informed by a reflection upon the overall application of cradle-to-cradle for Mars. “This approach prolongs the material lifetime while dealing with some of the trash issues in refugee camps and minimizing cost and environmental impacts of shipping and producing new materials.”

4 DISCUSSIONS

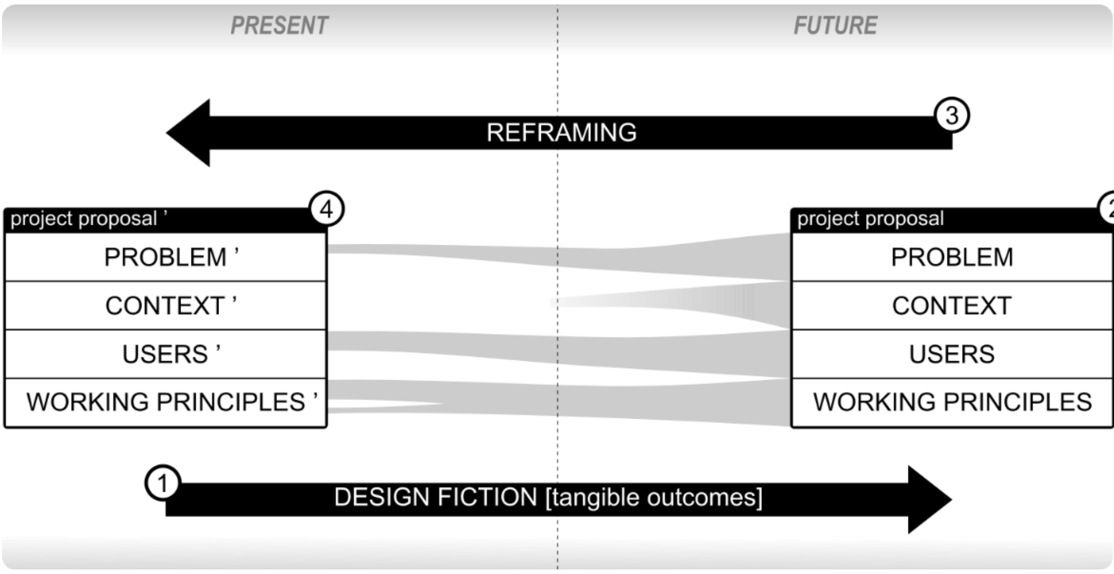

Figure 1. Proposed methodology for developing a project proposal for the future (2) by using design fiction (1) and reframing (3) it into the present (4) by bridging specific factors

The methodology presented in this paper (Figure 1) allows designers to use design fiction (1) in developing tangible outcomes that become part of developing a project proposal (2) for the near future, then reflect on several factors that define the proposal and reframe them (3) to create a project proposal for the present (4). The critical thinking involved in reframing for the present allowed design students to use the experience and findings from the project proposal for the future. Particular aspects from the problem, context, users and working principles provided a lens for finding real situations in which some of the factors were observed; and to address the discovered situation by reframing certain factors.
Reframing as a method for the feedback loop into the present differs from design fiction in that it does not include a set of recommendations reached after reflection. Comparatively, reframing allows for addressing the present at a more concrete level of abstraction, due to the development of tangible outcomes. However, because the future and present project formulations are not identical, this can be considered a limitation that must be addressed before this methodology can be used in design practice. An example of this assumption is that the loop in design fiction, while more abstract, still addresses similar factors from the future project formulation, and this may be included in a design brief for new product development in the present. Despite this limitation, reframing enables to tackle particular factors in present situations based on an experience gained from a problem-solving activity (developed to address the future situation). The creation of bridges between specific factors in the two project formulations (future and present) may allow designers to exercise critical thinking in ways other than mapping and analysis. It positions it more closely to reflection in- and through- action [7].
Overall, reframing from future-to-present facilitates mapping important elements of a problem-solution pair (as defined by [8] and tested with design teams by [9]) without biases that may arise when assessing a somewhat more familiar present situation rather than a future one. Furthermore, developing a specific product for the future that serves as a proxy for the present establishes a baseline for assessing both process- and product-related factors regarding the current problem formulation, requiring a new level of immersion in problems and their respective nuances. This process facilitates sensemaking by building on prior experience as well as previously established and reflected insights. Because both project

formulations are addressed through tangible outcomes, I argue this constitutes a designerly way of knowing [10] for industrial designers in the context of design education.
Understanding a design proposal as a system that is part of a supersystem and includes interreacting sub-systems, all evolving in a continuum of past-present-future is not novel [11]. I consider that the methodology here described enables students in developing critical thinking towards established factors of present situations that sometimes are implicitly accepted at the outset of design activity (e.g., quality of infrastructure, uninterrupted supply chain, resources availability, etc.). The presented case demonstrated that students were able to reflect on previously created insights and reframe them into new user groups and contexts and relate them with business (supply chain, cost, etc.) and technical aspects (technology development, materials, production, waste, etc.).

5 CONCLUSIONS

Future designers are expected to deal with increasing wicked problems and upfront dynamic complexity. The methodology here presented offers an approach to engage with underlying factors of wicked problems, learn from direct experience, and use tangible outcomes as a central part of the learning experience. The findings indicate that insights can be interpreted at various levels of abstraction and, when combined with critical thinking, stimulate the reuse of processual aspects and reframing of specific factors addressed in the future formulation into the current project formulation.
Future research can address the application of this methodology in project formulations for specific product typologies and predetermined time frameworks. This exploration can be pursued either in learning contexts or design practice. This would allow clarity on which factors are more prone to be reframed and how situations could be effectively described in correspondent problem formulations to allow designers to approach them in unbiased ways.

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¡EUREKA! DESIGN OF FLOATING LUMINARIES ON WATER: A LEARNING CHALLENGE IN ENGINEERING

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ABSTRACT
The learning space in the 21st Century cannot be limited to a closed space like the classroom. It is important to push the limits of creativity and innovation in the mind of the apprentice. Mixing dissimilar topics, awakening intrinsic motivation, and following a design methodology are the keys to achieve efficient learning. Challenge based learning is an integrative pedagogical approach that combines experience, cognition and behaviour. This approach takes advantage of students' interest in finding practical meaning to education, while developing key skills competencies in a world mediated by rapid technological advance and sustainability. In this paper, a pedagogical strategy is exposed to impact first-year students in the application of a design methodology and the development of competencies in graphic expression, manufacturing, critical thinking. These skills were obtained from the challenge of designing, materializing, and testing a floating luminaire that works from solar energy. These prototypes were manufactured with sustainable materials and processes, considering as an aesthetic/formal referent the work of Ernst Haeckel and as a physical principle, Archimedes' law to achieve buoyancy and stability on the water. The outcome of this learning experience was 56 luminaries that enlightened and floated over the water mirror of the cultural centre of the EAFIT University, the library Luis Echavarría Villegas.

Keywords: Learning challenges, sustainability, solar energy, creativity, luminaire, buoyancy

1 INTRODUCTION
Learning by doing has proven to be an efficient education strategy especially in disciplines related to engineering and design. Active learning is the center of the pedagogical model of Universidad EAFIT [1], the different methodologies that comprise it consider the student at the center of the training process and seek to strengthen applied knowledge without abandoning the importance of theoretical knowledge and reflection on the consequences of doing. Students become protagonists of their own learning process and teachers in the role of counsellors and boosters of the process. Experiential learning, as part of active learning, is an educational approach that seeks to challenge and learn by doing [2]. These types of projects are particularly useful for the development of skills such as critical thinking, autonomy, self-esteem, empathy, collaboration, and reasoning in search of pragmatic solutions. Project 2 is a first-year course, whose pedagogical objective is metacognition, how is it designed when you design? The course is focused on solving challenges around furniture and proposes two exercises, the first is aimed at the student developing a luminaire. This challenge proposes to combine different topics of study such as solar energy, Archimedes' law, and the inspiration around the work of Ernst Haeckel, so that the student summarizes it in a functional prototype integrating the theme of sustainability in six weeks. This challenge introduces the student to the use of alternative energies to design and confronts him with solving engineering problems that may be demanded in subsequent semesters. It also exercises he/she in the use of methodologies and tools to design that are fundamental in design and engineering education. Universidad EAFIT, with its motto - inspire, create, and transform - permeates its entire pedagogical model and in this course, this philosophy is responded to promote responsible innovation in the apprentice. This work shows the process of how students designed and manufactured 56 floating solar luminaires, which were exhibited to the university community as an example of experiential learning.

2 METHODOLOGIES

A five-step methodology was used, which was implemented for 6 weeks. See Figure 1. Its purpose was to develop a functional prototype of a floating luminaire activated by solar energy. In addition, it sought to develop competencies in students on concepts of firmness, utility, beauty, and sustainability [3]. It was also important to promote work in their processes of self-reflection and critical thinking.

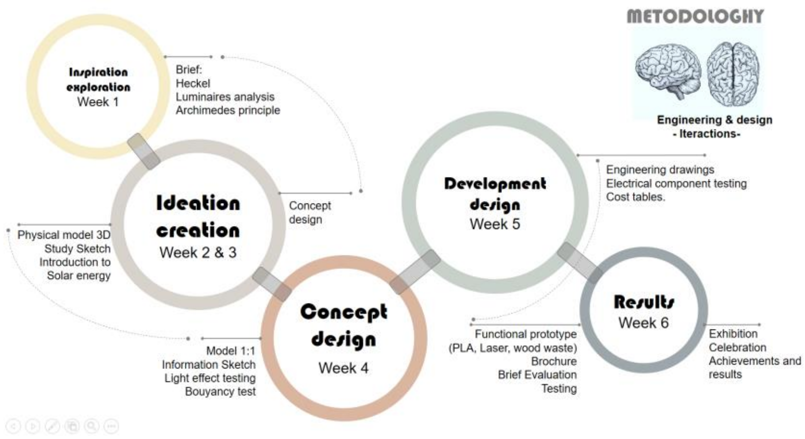

Figure 1. Design Methodology

2.1 Inspiration/exploration

The teachers presented the brief, the luminaire had to be based on the work of Ernst Haeckel, float, and rest on a flat surface, and generate a warm light for the home from solar energy. It began with the presentation of Ernst Haeckel's work "art forms in nature" developed between 1899 and 1904, as an element of formal inspiration [4]. The categories of study to investigate and make a formal exploration by the students were: Thalamophora, Diatomea, Desmidiea, Echinoidea, Acantharea, Spumellaria, Prosobranchias, Teleostéos, Ascidias. Parallel to Haeckel's exercise, they had to understand the operation of 2 luminaries, through the observation and drawing of its components. One luminaire was assigned by the teachers from a design website and the other they were able to choose the model from one physically available at a store or their homes. This stage ended with two activities within the classroom. The first one was the explanation of Arquines's law, and how to use it to calculate the buoyancy force and water line, the appropriate materials selection, and the way to protect the electric circuit. The second one consisted of showing a basic circuit assembled, their components and the range of dimensions available to start generating their design ideas.

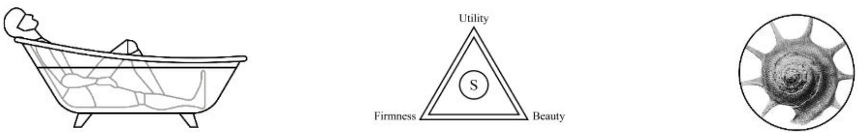

Figure 2. Subjects of inspiration stage: a) Arquimedes law, b) Vitruvio c) Haeckel

2.2 Ideation/creation

Through sketches, students had to present the formal exploration of their proposals from Haeckel's categories. Each had to explore the three dimensions, symmetry, proportion, and views of the concept on different planes. In addition, he had to ask himself: how to make a floating structure that can be a luminaire from the figure explored? How can Archimedes' law be applied to this structure? What materials could work in water? If you need to locate a solar cell, an LED, a transformer, and a switch; how would they be protected from the water? Subsequently, the team of teachers chose a concept for each student, which due to its geometry and aesthetics best suited the established requirements. After choosing the concept, the goal was to delve into the technical aspects of solar energy and the environmental benefit of using renewable energy sources [5]. The operation and calculation of the efficiency of a solar panel and the calculation of the type of battery required for the luminaire to operate for a certain time were explained. In the end, to materialize the ideas, the students had to make three study models in 1:6 scale with their respective sketches. In the following week, the most viable was chosen according to these requirements: cell size, location of the components, and formal reference.

2.3 Concept design

The student presented a 1:1 scale model and a sketch of the luminaire of the selected design concept; He tested some materials, created visual effects using a light source, experimented with the location of components, and did buoyancy tests based on Archimedes' principle [6]. For this test, the waterline of the study model was calculated by following steps as illustrated in Figure 3:

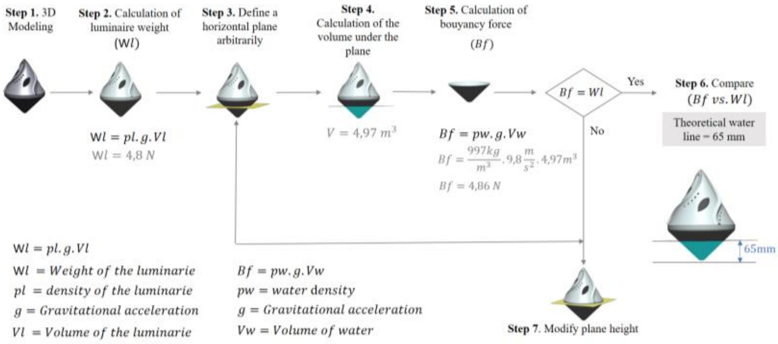

Figure 3. Calculation of buoyancy line

At this stage, students were advised to look for symmetrical shapes, volumes wider than tall, and low-density materials such as balsa, 3D printed parts with low fill density, and thermoformed polystyrene parts. From this exercise, it was possible to make changes of materials and distribution of weights of the components to avoid overturning and achieve better buoyancy.

2.4 Development and detail design

Once the design concept was selected, for each luminaire the circuit was defined according to the model and the studio sketch, to be able to define details for its construction. The corrections made considered aspects such as the scale, size and proportion of the luminaires, the internal circuit and its location, the type of LED and battery to be used and the elements and parts that could be simplified from the design to optimize manufacturing and flotation. A 1:1 scale drawing of the assembled luminaire was required, with section views to illustrate the location of components such as LED, solar cell, controller, battery, switch, and wiring to facilitate construction and assembly of parts.

2.5 Manufacturing, testing and evaluation

Finally, each student defined the electrical components, materials and assembly strategies that would allow them to build their concept in one week, based on the technical drawings, the information sketch, and the 3D sketch. Construction processes included 3D printing, laser cutting, thermoforming, plastic moulding with industrial dryer, plastic welding, and woodworking techniques such as cutting, sanding, carving, serial plane assembly and waterproofing. Once the prototypes were manufactured, they were evaluated under the aspects demanded in the brief. At this stage, slenderness corrections, switching to lighter materials and relocation of components were made. Also, the intensity of the light, its effects and the battery life were evaluated. In this way, some designs were modified and optimized. For the final exhibition, each student prepared a digital brochure with the product name and image in the space, name of the designer, materials used and design process. The catalogues were published on the **Issuu** platform. Those attending the exhibition were able to access the brochure through a QR code that each student had stuck on their shirt. The luminaries were exhibited in the water mirror of the university's cultural center in a celebration with live music and as an achievement of being able to show the results to the university community.

3 RESULTS

In this challenge-based learning project, 56 floating solar luminaires made of sustainable materials and processes were obtained, the results are described below.

3.1 Inspiration/exploration

The brief and Archimedes' law were analysed, two existing lamps were observed, and their components drawn. Also, within Haeckel's categories they selected one and studied its definition, shape, characteristics, and structures to generate a formal exploration and think about manufacturing materials. In the case of the Acqua project, the student selected the category of Prosobranquias, from the gastropod family.

3.2 Ideation/creation

The students selected from the previous stage three figures that were then drawn with volume and materialized with scale models to specify their shape. The exercise proposed the creation of a three-dimensional sketch through the exploration of a linear material [7], a planar material and a material that could be moulded. In this case, the apprentice used materials such as wire, paper and clay. See Figure 4. Care was taken to define shapes that could displace enough volume of water to favour buoyancy and house the solar cell. Model a) in clay was chosen for its symmetry, size, and the feasibility of locating the solar cell and circuit at the base.

Figure 4. Formal exploration, 1:2 scale models of the Acqua project in clay, wire, and paper

3.3 Concept design

To clarify the location of the circuit components, verify the buoyancy of the structure and manufacturing strategies of the final prototype, the students made a study sketch and a 1:1 scale model. Figure 5 illustrates the proposal for the Acqua luminaire.

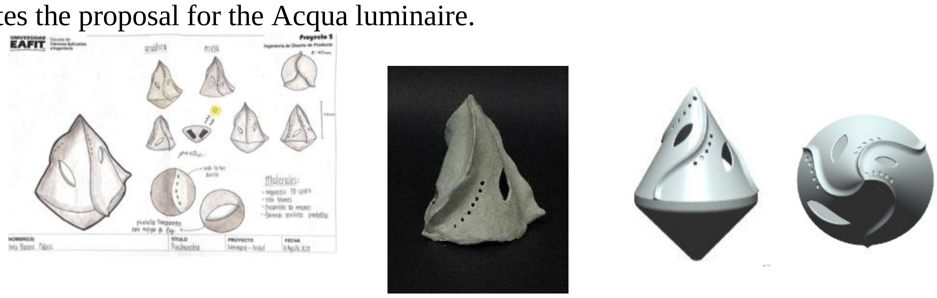

Figure 5. Study sketching and 1:1 scale clay model and modeling. Acqua Project

3.4 Development and detail design

The students developed a sketch with the following information: assembled luminaire with the graphic representation of the real materials, exploded drawing and a technical drawing detailing the location of the electrical components and their assembly, see Figure 6.

Some students generated a technical drawing from a 3D modeling in CAD software, as in the case of Aqua, while others carried it out manually on graph paper. Some students built their prototype modelled in clay, wood or air-dry modeling clay and then digitized it using a 3D scanner. In this way, they were able to export their creations to CAD software and generate a technical drawing.

3.5 Waterline calculation

Most students calculated the waterline from the three-dimensional modeling of their luminaires following the scheme proposed in Figure 3. In the case of Acqua, the total weight was 4.8 N and the volume of water displaced was 4.97 m^3. The water line was 65 mm from the lowest part of the luminaire. The 3D modeling can be seen in Figure 5.

3.6 Manufacturing, testing and evaluation

Once all the technical, formal and construction aspects had been reviewed, the students began manufacturing of their luminaires. Some were fabricated using 3D printing, wood carving, laser cutting and thermoforming. In the case of Acqua, 3D printing was used. Figure 6 shows the entire assembly and the buoyancy test.

Figure 6. Acqua information sketch and model in use,3D printing manufacturing and testing

Each luminaire was evaluated, the most relevant recommendations were related to shape, performance, and buoyancy. In some projects it was necessary to replace the materials with lighter ones, relocate and reduce the height of some parts to lower the center of mass to improve stability and buoyancy and avoid an overturning.

3.7 Exhibition and celebration

"The light is On XIV," is an academic cultural and artistic event conceived for the exhibition of the luminaries to the academic community, family, and friends. It is a presentation that takes place every six months since 2016 as part of the course Project 2. For this edition, the floating luminaries were exhibited in the water mirror of the library Luis Echavarría Villegas University Cultural Center. The students wore a QR code on their t-shirt with the link to the catalogue of each creation published in Issuu. Some of the achievements and results can be seen in Figure 7.

Figure 7. Exhibition at the Library Luis Echavarría Villegas Cultural Centre

4 CONCLUSIONS AND DISCUSSIONS

From **experiential learning** [8], the student was able to make a continuous cycle of reflection, conceptualization, application of knowledge and experimentation to verify the specifications of the design challenge. The exercise of the luminaire confronted him to learn, to be reflective, recursive and to work synergistically with engineering and design tools. It is an exercise to awaken your intrinsic motivation and prepare you for new challenges in topics such as solar energy [9], sustainability, and formalization. They also learned about the importance of following a design process and methodology in complex projects. In the **inspiration and exploration** phase, the exercise combined engineering, design, and art for concept development. Designing with a formal reference when learning to design facilitated the work of creation. Likewise, understanding how a solar circuit and a floating structure works and combining these concepts with the microorganisms that Haeckel researched, made the exercise innovative and stimulating for students' creativity. In the **Ideation and creation** phase, according to Rowena Reed: "all three-dimensional projects must be designed three-dimensionally, you can't design a good three-dimensional design on paper. You must deal with negative space, and you cannot do that in two dimensions". In this exercise, the exploration of three types of materials for the fabrication of the three-dimensional sketches from line, plane and volume was particularly important, it helped the student to find the material that made it easier for him to express the shape of his idea [10]. We consider this practice to be efficient and should be replicated in 3D object design exercises in the ideation and creation stage. In the **design**

concept stage, students had to integrate the parts. The three-dimensional sketch served to make a more precise drawing of the concept, clarify the idea, and then materialize it. The shape of the luminaire had to integrate the electronic components and promote buoyancy from an appropriate water volume displacement. In the **development and detail design** stage, modeling the luminaires using software allowed the waterline to be calculated more quickly, due to the ability to perform iterations using the computer. In addition, having a digital model allowed them to build many parts of their prototypes using 3D printing. The luminaires that were fabricated manually incurred slower iteration processes to find the waterline. In these cases, it was necessary to make changes directly on the physical prototype and test them in the water. Additionally, more time was invested in the fabrication of the models. The manufacturing stage demanded different skills such as modeling, drawing, using measuring instruments and assembling electronic components. On many occasions, the exercise required knowledge that was obtained outside the classroom with the support of the technicians and teachers. In the **testing and evaluation** phase, the tall structures, and the use of materials such as high-density wood caused some luminaires to sag or tip over. To improve the performance of some luminaires, it was necessary to use lighter materials, reduce the height of some structures, redistribute components, and change manufacturing methods. In addition, it was necessary to eliminate unnecessary parts and assemblies. Finally, regarding sustainability, the solar panels worked properly, and all the lamps had an autonomy of approximately two hours. It was important to promote in the students the importance of the use of renewable energies to integrate them in future projects and to make the students aware of the use of recycled or recyclable materials, to use the minimum of finishes and to avoid the project being discarded at the end of the exercise.

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WHAT HAVE WE LEARNT: REFLECTIONS PRE AND POST PANDEMIC ON THE TRANSITION TO ENGINEERING DESIGN EDUCATION ONLINE

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ABSTRACT
The COVID-19 pandemic had a significant impact on engineering design education and its delivery. In response to the pandemic, many universities changed to online teaching and learning, in order to reduce the spread of the virus and protect the health and safety of students and staff. The shift to online learning has presented a number of challenges for engineering design education, particularly in terms of providing students with the resources and support they need to continue their studies effectively. In July 2020, with a new online semester approaching, the Design Education (DE) Special Interest Group (SIG) of the Design Society prepared workshops with members of the Engineering and Product Design Education (E&PDE) conference and DE SIG communities to determine the challenges of moving online for the engineering design education community, and how to overcome these challenges. The workshop resulted in 12 challenges, and 5 solutions. A second workshop was conducted in September 2021 following the beginning of the return to on campus working. 19 challenges were identified and 16 solutions. Thematic analysis was used to identify relationships in the outcomes. By comparing the outcomes of the workshops, the community can better understand the gaps in knowledge of engineering design educators before and after the first full year of online learning and can learn from the innovative solutions created to overcome these challenges. This paper will share the engineering design practice changes reported by the participants of the workshops, and recommendations that will be useful to others who are similar transition in the future.

Keywords: Teaching online, online learning, digital, hybrid, COVID-19

1 INTRODUCTION
Engineering design education has experienced a recent paradigm shift. Online learning was once a novel concept where fully online courses were offered by a limited number of universities. A consequence of the global COVID-19 pandemic was a shift to online learning as the default for most universities during the period of self-isolation. For many, pre-pandemic on-campus education considered technologies to support distributed learning as a novel concept, as secondary to in-person education. The engineering design education community must consider if online learning is equal to in-person learning.

This extends to the demands of industry and students' skills development. Computer-Supported Collaborative Design (CSCD) skills are desirable to companies who operate across boundaries of location, discipline, time zone and other factors [1]. The ability of an employee to operate globally requires them to understand and utilise technology as the situation demands. In addition, it is becoming acceptable to collaborate online even when located nearby [2].

There remain challenges to overcome. Many students have struggled with the lack of access to physical studios and workshops, as well as the difficulty of collaborating with their peers and educators remotely, and the economic disruption caused by the pandemic has made it harder for some students to afford the resources and equipment needed to participate in online classes [3]. As educators, we should be aware of the challenges our students face to better support them. Design educators have been collaborating in their schools, departments, universities, communities and beyond to adapt to the new circumstances and find ways to support their students and continue delivering high-quality engineering design education. This has included a range of innovative approaches, such as using tools and online platforms to support engineering design education and collaboration [4] and feedback [5], novel methods of teaching [5] and designing [6], as well as providing additional resources and support for students who are facing financial or technological barriers [3].

This paper discusses the outcomes of workshops held with the engineering design education community. The purpose of these workshops was to better understand the experiences of the community before and after the first online year of the COVID-19 pandemic. Section 2 will detail the methodology of the study and the workshop setup. Section 3 and 4 will detail the results of the workshops and discussion of each workshop before comparing the pre and post COVID workshops. The workshops represent a snapshot in time and the gaps in knowledge of educators who were moving into an unfamiliar teaching experience. By understanding and recording this, we as a community can be better prepared to face these or similar challenges in the future. Recommendations for future research are made.

2 WORKSHOP METHODOLOGY

In this section the methodological considerations for the workshops and study as a whole are shared. The workshops took place using a video conference with 39 participants attending workshop 1 and 31 participants attending workshop 2. Mural.co was used as an online shared whiteboard allowing all to participate in sharing ideas recorded on digital sticky notes. This paper goes beyond the workshop by analysing the pre and post pandemic experiences of educators. The outcomes can only represent the knowledge of the engineering and design communities who attended the workshop and further research is required to generalise the results.

2.1 Workshop 1 – Engineering design education: Transition to online

In 2020 the first wave of the pandemic hit, and many countries deemed it necessary to request or demand that those, who could, work or study from home. Before the first full term online, a workshop was proposed with members of the Engineering and Product Design Education (E&PDE) conference and Design Education (DE) Special Interest Group (SIG) communities. The workshop was advertised as the Design Society Chat Room to the Design Society community including those who attended E&PDE 2020 through the online webpage and newsletter shared with this community. The first workshop aimed to identify two things:

- What are the challenges of teaching online?
- How can we overcome these challenges?

The purpose of answering these two questions was to better support the engineering design education community by sharing our knowledge and experiences.

2.2 Workshop 2 – Transition to Online: What have we learnt?

In 2021 restrictions were beginning to ease and many countries were returning to in person teaching once again. For some this was a full return, and for others this was a staged return with hybrid teaching or reduced time on campus. Again, the second workshop was proposed with members of the E&PDE and DE SIG communities. This workshop was advertised as part of the schedule of the E&PDE 2021 conference where delegates of the conference and member of the Design Society community were invited to participate. The second workshop asked the same questions as the first, these were:

- What were the challenges you faced in teaching online?
- How can we overcome these challenges?

By answering these questions, the community could share their experiences of the transition to online.

3 OUTCOMES OF THE WORKSHOPS

Outcomes of the workshops are presented in ***Figure 1***. Yellow and blue have been used to demonstrate connections within and between Workshop 1 and Workshop 2. Where no connection exists, this has been highlighted. The first workshop identified 12 challenges in the transition to online and five solutions to overcome these challenges. Solutions were not proposed to three of the 12 challenges. The second workshop identified 19 challenges experienced during the transition to online and 16 solutions to overcome these challenges of which one solution was proposed that did not relate to a challenge.

3.1 Comparison between workshop 1 and 2 – Gaps in knowledge

The expected challenges and experienced challenges were thematically linked to help to identify: (i) The challenges expected that were not experienced, and (ii) the experienced challenges that were not

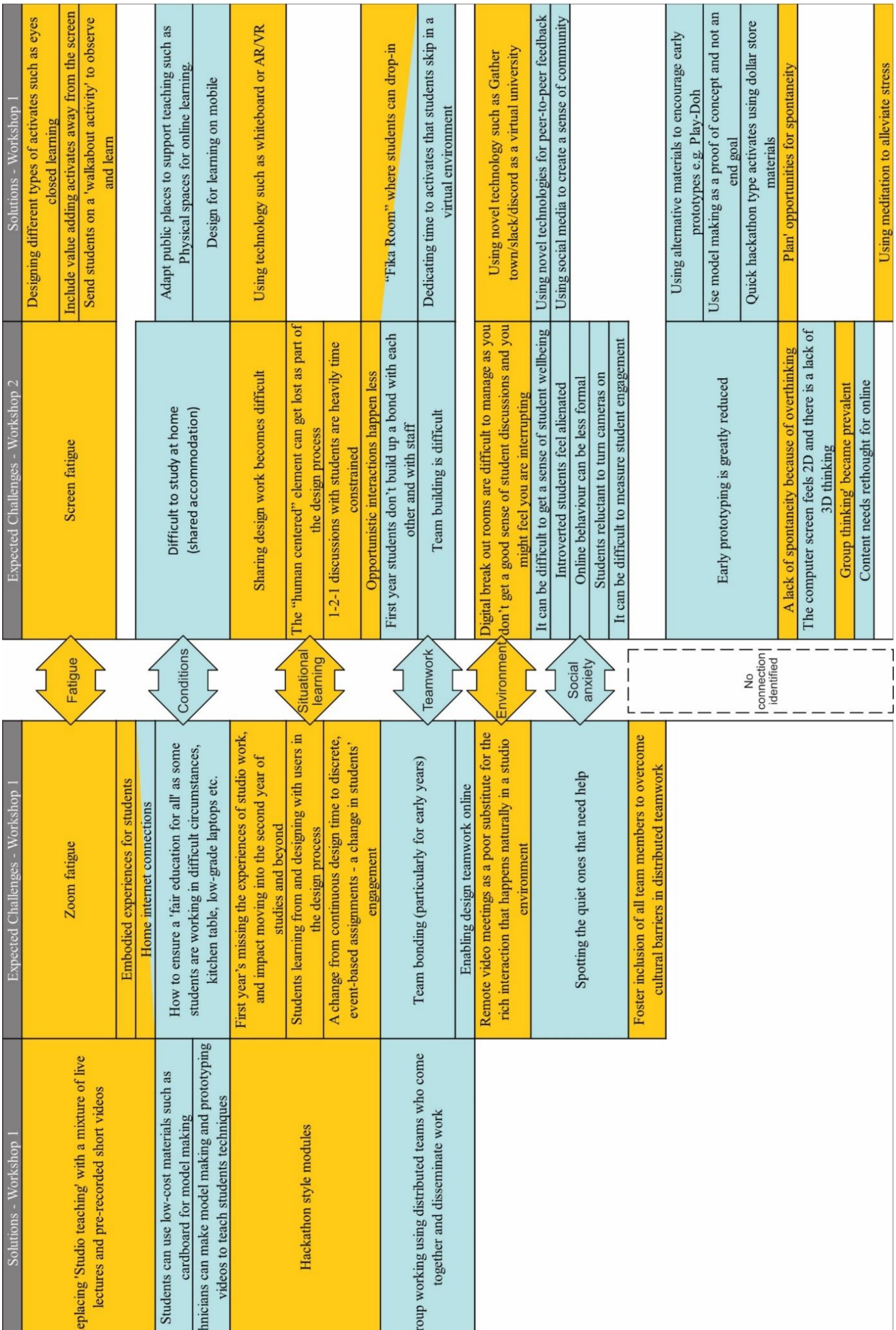

Figure 1. Outcomes of workshop 1 and workshop 2 mapped with thematic connections

expected. Comparing the expected challenges from workshop 1 and the experienced challenges from workshop 2, there were three expected challenges that were not experienced. These are:

- Remote video meetings as a poor substitute for the rich interaction that happens naturally in a studio environment.
- Spotting the quiet students that need help.
- Foster inclusion of all team members to overcome cultural barriers in distributed teamwork.

In addition, there were five experienced challenges that were not expected. These are:

- Early prototyping is greatly reduced.
- A lack of spontaneity because of overthinking.
- The computer screen feels 2D and there is a lack of 3D thinking.
- Group thinking became prevalent.
- Content needs rethought for online.

4 DISCUSSIONS

In the discussion section, the reasons for the challenges in the transition to online are discussed. The purpose of this section is to determine the research required to overcome these challenges that the engineering and product design education community can tackle in the future.

4.1 What we didn't know?

During workshop 1, two challenges were identified in which solutions were proposed in workshop 2, one challenge was identified in workshop 1 and 2 with no solution, and two challenges were identified in workshop 1 but not workshop 2.

The outcomes of workshop 1 were identified as: remote video meetings are a poor substitute for the rich interaction that happens naturally in a studio environment, it is difficult to identify quiet students that need help, and it can be difficult to encourage inclusion of all team members to overcome cultural barriers in distributed teamwork? Following the second workshop it was identified that remote video meetings remained a challenge specifically using break out rooms. Also, identifying quiet team members remained a challenge to evaluate student wellbeing, students feeling alienated, the sense that online can be less formal, students are reluctant to turn their cameras on and that it can be difficult to measure student engagement. Solutions were identified including the use of novel technology such as social media to support a sense of community and peer-to-peer feedback [7].

Fostering inclusion of all team members to overcome cultural barriers in distributed teamwork was identified as a challenge in workshop 1 which was not mapped to a challenge in workshop 2. This was suggested for reasons of: it is a perceived challenge but not a challenge that exists in reality, or the experiences observed by educators did not identify this as a problem through lack of aware ness or misidentifying the root cause of the problem. An example of this from distributed design literature is cultural attitudes towards organising and attending meetings. The behaviour of some cultures to organisation in a distributed group can be interpreted as laissez-faire. However, an educator may interpret this as the students being unprepared or busy with other classes. Therefore, the solutions they may suggest may not be appropriate [8]. Because inclusion of team members and overcoming of cultural barriers was not identified as a challenge in workshop 2 it indicates that further research is required.

Two challenges, enabling design teamwork online and embodied experiences for students, were identified in workshop 1 but not in workshop 2 which indicates that these expected challenges were not realised. These may have been identified as challenges in the moment but did not remain a challenge for a long time. Guidance from universities and the engineering design education community may have helped to overcome these challenges promptly.

4.2 What we still don't know?

Following workshop 2, five challenges were identified in workshop 2 that were identified in workshop 1, three challenges were identified in workshop 2 that were not identified in workshop 1 with no solutions, and two challenges were identified with no solution.

The six challenges identified in workshop 2 that were not identified in workshop 1 represent were unpredicted. These are: getting a sense of student wellbeing, the "human centred" aspect can get lost as part of the design process, 1-2-1 discussions with students are heavily time constrained, students are reluctant to turn cameras on and online behaviour can be less formal. Solutions remain as research challenges. Technology can support awareness of student's progress if we identify suitable technologies and implement their use. In addition, educators need time to reflect and redesign courses improving the quality of lessons, as we typically do with in person courses based on student feedback. This could be solved by continuing hybrid teaching post pandemic. Hybrid will allow educators to continue to develop lessons online and in person for agility in the delivery method. Beyond the challenges identified, it is prudent to consider how learning can suit lifestyle and the role hybrid learning plays in this. With greater acceptance of online learning as a result of exposure during the pandemic, communities of learners have become more accepting of online learning. To support an excellent student experience, we must consider the appropriateness of learning experiences.

The three challenges, the computer screen feels 2D and there is a lack of 3D thinking, content needs rethought for online and "group thinking" became prevalent in teams, were identified in workshop 2 but were not identified in workshop 1 with no solution, represent challenges we did not foresee and areas for further research. There is extensive research into how designers think in the research field including [9, 10] and this may be extended to analyse the issue of thinking in 2D versus 3D when using digital tools. On the second challenge, rethinking content, the discussion hybrid is also relevant, and this may identify further challenges. On the third challenge, "group thinking", there is research in the wisdom of crowds [11], how people act in groups versus individually, and also in tools and techniques to support independent thinking [12]. This may be brought into the classroom where applicable.

Three challenges identified in workshop 2 with no proposed solutions were: early prototyping is greatly reduced, and a lack of spontaneity because of overthinking. Prototyping can be encouraged more. There was a solution to encouraging prototyping within workshop 1 by using low-cost materials. However, without encouragement there can be a different mindset when designing at home. Perhaps the reliance on the computer to communicate, and to progress the project puts the design student in the mindset that the project development should be digital. Educators perhaps need to rethink how to encourage a hybrid approach to design. Considering spontaneity, which was also identified in workshop 1, a solution may be to plan time spontaneity. 'Digital' can bring a logical approach which can lack creativity [13] depending on the designer and their approach. However, there is a lack of hybrid design methodologies to bridge the gap between online and offline working. There are some recommendations on how to best work in a distributed environment, but these are developed to support students, the next generation of designers. Further research is required to better understand the design processes of engineering designers in industry, understanding and highlighting that there can be co-located and distributed design activities throughout the design process.

4.3 How can future educators be prepared?

Next steps have been proposed to ensure educators are agile in their teaching pedagogy, no matter the global situation, and students are building the right knowledge and skills to be equipped to design whatever the future may bring. Recommendations are:

- Further research is required into novel ways of teaching and conducting design online. This may be the development of new software, new functionality of software or new processes and procedures to overcome technological challenges.
- Further solutions are required to better measure student welfare. It may be appropriate to bring functionality of social media to support this.
- Better prescriptive guidance from the global design, distributed design research community, and others, on how to overcome challenges of teaching and learning online; as well as an assessment of the research in this community to better understand which challenges still exist.
- Teaching hybrid classes will allow educators to improve the learning experience both online and in person. If there is a need to switch to fully online again, the quality of the learning experience can be guaranteed as there has been the opportunity to improve year on year.
- Finally, there is an opportunity to define the hybrid design process. How can a designer be agile when online or in-person? How can they easily switch between medium and ensure a robust product development.

5 CONCLUSIONS

This paper details the methodology and outcomes for a series of workshop to better understand the knowledge of engineering design educators pre and post pandemic. COVID-19 changed engineering design education and there is now an opportunity to learn from the collective experiences of the community to ensure that educators and students are better prepared for future pandemic-like situations. The workshops have enabled a better understanding of the gaps in knowledge of educators post pandemic and an understanding of the challenges still faced in engineering design education. Recommendations have been shared to further the research field to develop solutions to problems still faced including the need to better understand novel ways of teaching and conducting design online, better measures of student welfare and to better hybrid design methodologies that are agile to external demands. Guidance should be shared from established research communities where appropriate e.g., from the global/distributed design communities. Hybrid education brings opportunities to ensure that both online and in person education remains high quality ready to change to online when required. The authors are excited to work with the community in addressing these challenges.

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TEACHING PRODUCT DESIGN MORPHOLOGY: MATCHING EDUCATIONAL GOALS WITH AFFORDANCES OF DIGITAL TOOLS

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ABSTRACT
Industrial designers use several kinds of representations to support reflection-in-action while developing design proposals. The affordances provided by digital tools impact the flow of shifting between different representations, thus influencing the ability for reflection and discussion. This fact challenges tutors who need to plan industrial design courses in digital learning environments.
This paper addresses planning a product design morphology course delivered in a digital learning environment in the context of problem-based learning. The study reflects upon the externalisation of knowledge and how it impacts the matching between educational goals, learning activities and the affordances of digital tools. Particularly the relationship between designing active learning experiences with conscious considerations of specific affordances provided by digital tools that students directly interact with. A reflection following the course delivery revisits the planning process and proposes a two-phase framework to consider overall and detailed pedagogical reasoning. The framework allows different levels of reflection towards designing learning activities by considering the use of the affordances of digital tools both in online learning environments and professional practice.

Keywords: Affordances, online teaching, pedagogical reasoning, industrial design, external representations, reflective practice

1 INTRODUCTION
The problem-based model is centred on the individual learner. The study activities contribute to empowering the learner in applying knowledge to solve real-world problems by using the ability to critically reflect on the problem, use appropriate resources, work in teams, and communicate effectively with others [1]. Such a definition finds commonalities with Schön’s [2] postulation on the reflective practitioner, which is a cornerstone in industrial design reasoning. According to Schön, the process of designing, in which designers transform an ill-defined problem into a solution, is based on an ongoing reflection in action. The practitioner engages in both self-reflection on internal tacit knowledge, and externalisations of knowledge such as drawings, annotations, and verbal communication, and recalls previous experiences with similar or analogue situations to infer decisions on the project under development.
In online learning environments, access to different kinds of representation hinders design discussions. The flow of design discussions, where one makes use of different kinds of representations to communicate an idea or discuss a particular aspect, does not reach its full potential because of the affordances provided by digital tools and limitations of the medium. This fact poses challenges when designing online learning experiences, in particular in matching the educational goal, the goal of the task and the available affordances of digital tools [3]. Recent research [4] proposes that the educational goals and the decision-making process responsible for transforming the goals into pedagogical strategies for learning must be reconsidered before and during teaching in digital learning environments. In reconsidering the pedagogical strategies, educators must “have a systemic understanding of teaching content, teaching and learning processes, student needs, and dynamic characteristics of online environments to make appropriate instructional design decisions (i.e., transformations) for their pedagogy and teaching practices.” To fulfil the systemic understanding of the educational goals Stephaniak et al. [4] propose a framework encompassing the planning of courses with the support of a)

external representations and b) the use of reflection-in-action to establish a solid foundation, followed by c) conjecturing strategies for the delivery. The authors conclude that the three-step framework enables better dynamic decision-making practices about technological challenges.

The case study presented in this paper details aspects that are proposed in Stephaniak's study, but not specified. In particular, how affordances in digital learning environments are generally characterised as different from traditional learning [4, pp.2235-36]. I hypothesise that digital affordances can be further investigated if we break them down into steps that help students achieve certain educational sub-goals through specific tasks. In the present study, I present a case study that exemplifies the process of learning design in setting educational goals and learning activities and matching those to affordances provided by the online collaborative tool Miro.

In industrial design processes, externalisations of knowledge involve multiple outcomes that range from iconic representations, such as photos, sketches, 3D models or physical models to symbolic representations ones such as schemas, diagrams or textual annotations [5]. These externalisations are key to the process of idea development because they enable designers to elaborate on their ideas – from clarifying problems to maturing and testing potential solutions – and receive feedback from peers and tutors, that constitutes an important pedagogical strategy in engaging students in what Schön refers to as a "reflective conversation with the situation". Kolko [6] highlights that "once externalized, the ideas become "real"–they become something that can be discussed, defined, embraced, or rejected by a number of people (…)". The underlying notion is that easy access to documentation and an overview of the different kinds of representation may facilitate the reflection-in-action regarding implicit and explicit relationships that ultimately lead to better decision-making. Kolko states the importance of mapping these externalisations in a physical space to facilitate sensemaking. Even though such premise cannot be directly undertaken in digital learning environments, it can be emulated through affordances of digital tools.

This paper presents a case study on the development of a course in product design morphology that focuses on the relationship between technology and form. More specifically, in the process of transforming the educational goals into pedagogical strategies for online delivery. Product design morphology requires students to develop form-related aspects of a specific object and link those aspects to others such as materiality, manufacturing, meaning, and user interaction. Students must engage with an experimentation process encompassing the generation of multiple representations – that constitutes an important part of the learning experience – as means to externalise knowledge that can be reflected upon to evaluate overall aspects such as composition, proportions, configuration or meaning; and specific ones, such as the arrangement of components, joining and functionality of sub-assemblies or material choices.

By unravelling the process of matching educational goals and learning activities with specific affordances, this study aims to contribute to pedagogical reasoning in digital learning environments, particularly in the field of industrial design and problem-based learning.

2 COURSE STRUCTURE

2.1 The domains of technology and form

The pedagogical practice here described was addressed in the context of the course "Technology and Form", 5 ECTS, in the MSc in Industrial Design at Aalborg University. The learning objectives were already established and were not changed. Overall, the knowledge, skills and competencies that students must accomplish by the end of the course focus on a) the development of advanced skills in the combination of technology in products or for producing products and b) visual understanding of form and composition in a product design for a given context. These educational goals are transformed into teachable subjects through a framework under which relationships between technology and form occur and directly impact industrial design practice.

The framework encompasses three domains: design, production, and paradigm. Design has outputs directly connected to production and both are set under a technological paradigm. The interplay across these three domains depends on multiple factors, however, in the context of the course, we focus on how the industrial designer can interpret technology development under at least one domain and explore it to create a product and associated design language that embodies a certain position towards the selected domain.

Regarding design, the development of computational technologies [7] is presented as enabling new possibilities for form generation and form evaluation. Production technologies are correlated with their impact on the design language of products in terms of technology pull or push [10]. The overall domain under which design and production occur is the technological paradigm [11]. In the context of the course, students are prompted into reflecting upon emerging paradigms of techno-social systems of production and consumption (e.g., distributed manufacturing, mass customisation, circular economy).

2.2 The assignment

Each student must design a multipurpose chair and conceptualise an offspring (which can be another type of seat, like a chaise lounge, armchair, bench, etc.) in the same design language. The chair should represent the student's interpretation of a potential future role of technology in the selected domain of design practice (design, production or paradigm).

The assignment development must accommodate two constraints. The first is the selection and reflection upon (at least) one domain to create the design brief for the chair development. The second is the use of a visual chair ontology [8, 9] in the design process for representing chair parts and its relationships.

The academic evaluation includes the submission of two posters and a paper reflecting on the process, and approach to technology under the selected domain.

Evbuomwan and co-authors [12] characterise three main models of design activity: prescriptive, descriptive, and computational. Prescriptive models analyse the overall design process and propose systematic steps to achieve the goals. Descriptive models characterise the designer's activities during the realisation of the design process. Computational models are concerned with the use of computational techniques to perform different activities throughout the design process.

In "Technology and Form" students develop their work based on a prescriptive model influenced by a computational model. The reflection document enables students to have an overview of the process, thus fulfilling the goal of descriptive models. The pedagogical goal is that students have direct experience with different models of design activity during the development of the practical part of the assignment, and the reflective document enables a post-experience analysis that consolidates the new experience and learning [13].

3 LEARNING DESIGN, EXTERNAL REPRESENTATIONS AND AFFORDANCES

Table 1. Main affordances of digital tools in lectures and studios

Main affordances of digital tools	Learning activity	
	Lecture	Studio
Write	●	●
Upload images	●	●
Manipulate objects	●	●
Collaboration with peers	●	●
Zoom / Pan		●
Sketch		●
Establish visual relationships		●
Shift across other applications		●

The learning design considers a dynamic unfolding of the overall educational goals and learning activities in sessions that includes lectures and studios. Lectures aim at introducing themes, terms and learning resources that can be further explored in the context of self-learning and encompass active learning methods that are student driven in order to allow them to relate the presented themes with their own practice (i.e., group discussions). Studios serve the purpose of enabling discussions about the work in progress and require students to prepare material beforehand. Studios allow for feedback from peers and tutor to prompt further reflection.

Overall, there are more lectures in the first half of the course and a progression towards studios and more student-driven activities as the course progresses. Each session of the course is structured by matching specific educational goals onto specific learning activities. Furthermore, the required affordances of

digital tools were correlated with the type of learning activity, and who drives the activity (tutor or student). Table 1 summarises the main affordances of Miro to be used by students.
Writing, uploading images, moving text on the board, support the discussion activities in breakout rooms prompted by lectures. These affordances would be further used in studios, in addition to establishing visual relationships between areas of an image and a note, zooming into areas of an image, panning across different representations, colouring diagram nodes, sketching, and shifting between software applications to clarify specific techniques or procedures.
When considering the overall delivery of the course and the required affordances of digital tools, the affordances used in lectures enable a learning curve for students who have never used the tool, to have practical know-how of using such affordances, that will be used together with other affordances in studio activities (Table 1). This reasoning allowed for clarification of the strategies for delivering the course and the external representations to support it. In tutor-led activities, external representations encompass the design of templates on Miro for group discussions, for pinup sessions (Figure 1) and for the using the visual chair ontology, in addition to specific instructions on lecture slides.

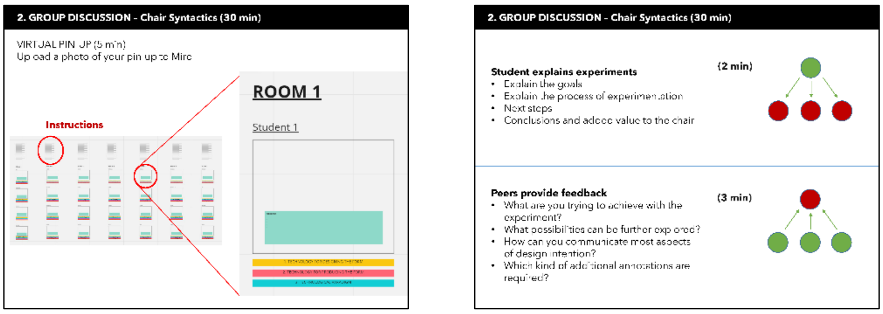

Figure 1. Example of slides explaining how to use Miro templates in a studio session.

Figure 1 shows external representations created by the tutor to be used in class. On the left slide the templates on Miro are shown organised into student groups and one is magnified for additional clarification of the task. The right slide details the task instructions, also shown on Miro.
The design of templates fulfils the goal of decreasing the need for changing fonts and sizes and organising elements, thereby providing a common structure that becomes recurring for each time the learning activity is pursued. The overall educational goal is that group discussions become a repository of information that can be revisited by students during the design process to facilitate reflection-in-action. Group discussion allows students to summarise to others what they have learnt, analysed, compare strategies, and relate to their previous experience, thus tackling the relational level of understanding [14] that can be then applied in problem-solving.

4 DISCUSSIONS

The case presented in this paper is positioned on problem-based learning theory [1], in considering the role of the tutor as a learning facilitator, of students as being responsible for self-directed learning, and in problem formulations that have ill-structured elements that act as drivers for student inquiry – in this case, the reflection about technology in a selected domain. The case focuses on a product morphology course addressing the relationship between technology and form, delivered online. The planning of activities encompassed external representations, reflection-in-action, and the conjecturing of strategies for the delivery based on affordances as defined by Stephaniak et al. [4]. Based on the experience of planning and delivering the course (one time online and two times hybrid), I consider that the planning phase of learning activities occurs under two phases summarised in Figure 2.
The first phase involves the overall interpretation of the educational goals into a rationale that is actionable from which conjectures can be formulated regarding how the educational goals will be translated into the overall course structure which includes the assignment, deliverables and sessions. External representations in this phase mainly consist of secondary data, annotations of potential ideas and matching those to educational goals and course structure. Reflection-in-action supports the refinement of the matching.
The second phase requires unfolding the previously established educational goals into sub-goals, and the course structure into: assignment phases and deliverables; sessions and types of learning activity;

the role of tutor and students in the learning activities; and a characterisation of the required affordances that students directly interact with. In this phase two types of external representations are produced: one that supports reflection-in-action for the tutor, and another that is designed for direct interaction with the student (e.g., Figure 1). The first type of external representations becomes crucial as multiple parameters must be assessed, and the role of the tutor and of the student must be situated in regard to guidance, feedback, critical thinking, problem-solving, etc. During this phase, these external representations and reflection-in-action enable different strategies to be defined and critically assessed, and potential problems to be addressed. This has a direct impact on the timeframe for the learning activity, and the need for strategies to reduce cognitive loads of students based on estimating the affordances of digital tools that will be subjected to direct interaction. This critical assessment leads to the development of the second type of external representations such as the design of templates, the use of similar elements throughout the collaborative online platform, and of instructions on the slides.

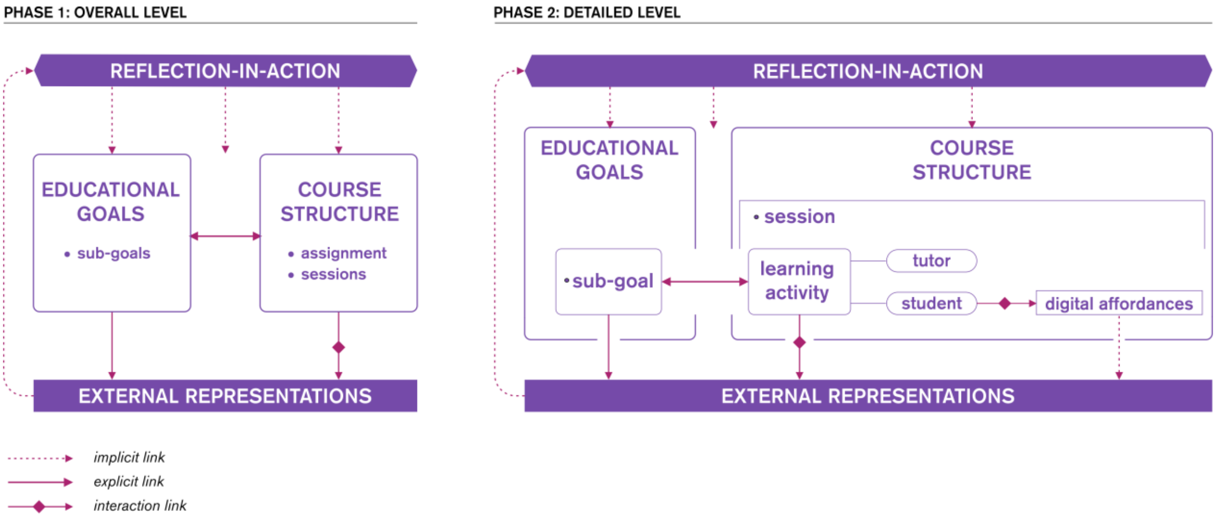

Figure 2. Phases of planning activities for digital or/and hybrid learning environments by correlating educational goals, course structure and affordances of digital tools.

This process of planning learning activities made me shift the focus to students as individual independent learners and find a different approach from upfront material that must be learnt and applied, to designing a set of activities that incrementally scaffold each other. These activities vary in their nature: some were presented in lectures, others in references for further reading, and others in peer-group discussions and practical tutorials. In writing the instructions for activities, I tried to be as clear as possible to minimise interpretation: by clarifying the level of difficulty of the task, by clarifying the output and how the output related to the assignment and industrial design practice. Together, these steps made me revisit the goals of the course several times, thus assessing the overall robustness of the course. To summarise, the goal is to create activities that students can use in self-directed and self-regulated ways in their learning; to find ways of being more explicit, how to trigger certain activities, or recap key points of complex activities; and to clearly define the minimum level of proficiency students must achieve to fulfil the educational goals.

The pedagogical challenge of addressing student engagement with online tools to externalise ideas in product development enabled me to break down the complexity of the design process for students into a set of phases, stages and series of steps to create a design proposal. This assessment was made together with the alignment between educational goals and assignment tasks. Designing activities that would activate knowledge transmission to students made me rethink my approach to teaching and engage in a deeper level of reflection about mechanisms to trigger self-regulated learning.

Based on this experience, I consider that the current digitalisation in higher education must address affordances with a higher level of detail, estimating how they can be used in digital or/and hybrid learning environments according to specific practices of the disciplines involved, in this case, industrial design. By focusing the discussion on affordances and not specific tools, we can estimate how these affordances contribute to the larger scope of the professional activity. As an example, in this course, the overview of the product provided by the use of the visual chair ontology during the design process, finds similar principles of application in computer-aided design when setting up a parametric design model, or in rendering software when defining settings through nodes.

5 CONCLUSIONS

This paper presents a practical application of a conceptual framework that outlines the steps for assessing affordances in digital learning environments [4]. Building upon the practical application in the case study, I propose that the operational planning of activities should encompass two phases (Figure 2): one for overall alignment and one for detailing. During the detailing phase, the alignment of sub-goals with learning activities must consider the specific affordances offered by digital environments. Externalising the thought process through representations is key to supporting reflection-in-action. As a result, critical assessment guides decision-making for designing specific learning activities. This includes the development of strategies to minimise cognitive load for the identified affordances, such as creating templates or using analogies from other tools commonly used in professional practice for illustrative purposes. In the end, these strategies contribute to situating the affordances in a larger context of practice.

The planning of learning activities should include discussion with peers. The need to explain out loud the pairing between an educational goal, a learning activity and specific affordances leads to engaging in reflection about it. The feedback pushes reflection toward deeper levels of learning mechanisms, that support refinement prior to delivery. Moreover, it allows for discussing methods based on previous experiences from tutors, and thereby conceptualising new learning experiences.

Future work under the application of the proposed framework could assess the relationship between affordances, learning activities and motivation levels of students, in particular, if there is a change in the motivation level from the beginning to the end of the course.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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DIGITAL TECHNOLOGY IN ENGINEERING DESIGN TEACHING

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ABSTRACT
Digital technology is widely used in engineering design teaching, enabling students to create parametric models of their solutions and data files for computer-aided manufacture (CAM). However, the digital industry is predicted to grow significantly throughout the decade and, in particular, digital twin applications. This paper compares the digital environment in engineering design teaching at two universities in terms of how their design teaching uses digital methods. The design projects and units in which digital technology is taught are identified and compared to give a broader understanding of the benefits and challenges to the teaching delivery. The different levels of technology in the digital environment are mapped against the academic years to understand the teaching strategy for large cohorts of students.
At both universities, design teaching uses drawing practice to build the fundamentals of CAD modelling and give students the opportunity to manufacture their own designs by using digital technology to produce CAM data files. Both universities deal with large cohorts and have adopted different strategies for dealing with the inherit challenges this brings. The delivery of digital simulation is shown to be similar, but contrasts at the digital twin level, where significant resource is committed.

Keywords: Digital technology, engineering design, undergraduate

1 INTRODUCTION
Digital technology is an essential part of design teaching as it enables students to create parametric models of their designs and data files for computer-aided manufacture. The adoption of such technology in engineering is expanding from the increased availability of 3D printers in workshops and at the personal level. On the global level, the digital industry is predicted to grow considerably, supported perhaps by confidence from the use of technologies throughout Covid-19 pandemic. An advanced approach within the industry is a digital twin. A digital twin is a virtual copy of a physical object connected by data transfer between the two. An important use of a digital twin is that it can provide information on how the real-world changes over time, but to be a digital twin the model must be associated with an actual physical object [1]. From 2022 to 2029, the global digital twin market is predicted to grow from nearly 9 billion to 96 billion USD [2].
The focus here is on the design teaching in undergraduate mechanical engineering courses at two universities, the University of the West of England (UWE) and the University of Bath. It is on the extent to which they include digital technologies when teaching engineering design. Equipping students with digital technology skills is valuable for industry and the placement year, but as cohorts are now over three hundred, careful planning and resource are required to ensure the teaching delivery is effective. To assist in appraising how the different types of digital technology are learned, they are considered within a digital environment comprising digital technology, digital simulation and digital twin. Digital technology is essentially a standalone programme which gives some form of output, such as, a CAD model of a design. Digital simulation explains how that design responds to set inputs, and a digital twin is as above.

2 DESIGN TEACHING

This section describes the design teaching at the University of Bath and UWE.

2.1 University of Bath

In the Department of Mechanical Engineering at Bath, the course structure comprises a four-year MEng, in which there are five programmes (mechanical, aerospace, automotive, design and manufacturing). All programmes are taught together in the first two years, followed by compulsory and chosen options in years three and four, respectively, that adapt the curriculum to suit the programme. Students may choose an industrial placement year after the second year.

This section describes only the design teaching common to all undergraduates which occurs in the first two years. The five programmes are taught together as one cohort, which gives the benefit of all students receiving the same delivery but presents resource challenges for a class size now of over three hundred.

Table 1. Structure of design units at Bath

	S1	S2
Y1	Design 1	Design 2
	2D/ 3D CAD (I)	CAD (I), CAD(G) BoM
Y2	Design 3	Design 4
	CAM data files, numerical model	CAD(G)
Y3		GBDP
		CAD(G) FEA(G) CFD(G)

In the first semester of year 1, drawing practice is taught through both hand drawing and CAD. Here the learning and assessment is on an individual basis, denoted by (I) in table 1. Students take their first step into design in the following semester in a constrained exercise and an open exercise. In the open exercise, students work in small groups and use parametric software to now share and co-develop parts and assemblies, denoted by CAD(G). In this group activity, design runs from concept to making and assembling a prototype. This exercise is set up as a “novelty” design to enable groups to create a range of concepts [3]. To facilitate the make, students use digital technologies to create CAM data files for computer-aided manufacture of their bespoke 2D and 3D CAD parts. In the second year, students simulate how stress is distributed across a structural part in a sub-assembly. The simulation is created by stress calculations and is a virtual digital technology. Further experience of CAD(G) is acquired in the Design 4 unit, but this time it is in a design of a production machine and factory layout. In the second semester of Year 3, all students study full-time on a group design and business project (GBDP). There are a range of projects from university-based competition projects, such as, Formula Student, to industrially sponsored projects. This full-time, semester-long unit enables the groups to create solutions with parametric CAD models and perform analysis and simulation, where appropriate, using FEA and or CFD.

2.2 UWE

This section considers Years 1 and 2 at UWE in the School of Engineering. For mechanical, automotive, and manufacturing students, design is both a vertical and horizontal thread across the first two years of their BEng degrees.

From a vertical perspective:

Within a year-long, first-year Engineering Practice module, students are introduced to three design methodologies of Double Diamond [4], Stanford Design Thinking [5] and IDEO: Human Centred Design [6]. It is demonstrated via case studies how these can be used to produce solutions for the project week activities later in their studies. In the final weeks of the module, students are also taught how to draft and generate 3D models and assemblies within a computer-aided design (CAD) package. Students are assessed using the SolidWorks CWSA certification process for CAD understanding, their application of the design process is undertaken during the project weeks.

When students transition into year two. In their second-year design module, students are required to follow an engineering design process for the development of a machine system. They are introduced to Pugh's, Total design [7], Systematic design [3], and BS7000 processes [8, 9]. The second-year project has an electro-mechanical flavour as the students are required to design mechanical components, such as, power screws, gears, shafts, and cams. They size and select appropriate actuators, required sensing technologies and control systems, generally PLC or microcontroller (system dependant), programmed as required. Students also size and select standard components, bearings, fasteners, couplers etc. The project is also constrained by environmental and sustainability limitations, health and safety, cost, and risk assessment issues. Students are expected to use Matlab [10] to perform any calculations or to create parametric model development. Although there are some electromechanical experiments in the module, the output of this project is a virtual concept. Students are assessed on their design report, Matlab scripts, assembly and manufacturing drawings, and via a presentation to the "client".
Students on the mechanical with manufacturing pathway take an additional unit where they explore the concepts of design for manufacture and assembly. Students are taught a range of DfX approaches, for additive manufacture, rapid changeover for automation, as well as Boothroyd and Dewhurst main methodology [11]. The students employ these methods on an industrial system, or on the Festo and Siemens cyber-physical smart factory [12] on campus aiming for improved manufacturability. The DfX activities are assessed via a technical design report and viva. Independently of these modules, students are taught how to use finite element modelling to analyse and develop structural design and computational fluid dynamics via Ansys workbench [13]. The ability to use FEA as a design tool is assessed via a plate with stringers type problem.
From a horizontal perspective:
The School of Engineering runs two project weeks per academic year, where the mechanical and automotive students are joined by civil, aerospace, robotics, and electronics students to work on an integrated design problem. To date these project weeks have utilised the problems set by Engineers Without Borders [14]. The project weeks are attached to the Engineering Practice units in each year. During these week students are exploring issues of transportation, sanitation, water security and other infrastructure problems found in areas like Northern Australia, India, South Africa, and Scotland. The integrated teams are expected to systematically employ the IDEO: Human Centred Design process [6] while producing their solutions. The outputs at the various stages of this design process form the assessments for the respective module within which they sit. Reporting takes the form of posters and a presentation.

3 DIGITAL ENVIRONMENT

3.1 Digital levels

The need to reflect on digital technologies in teaching is prompted by both the projected growth of digital twins (Fortune Business Insights) and the increase in research activity noted in this area [17]. To help interpret the form of digital environment used in teaching, three categories are used, digital technology, digital simulation and digital twin. An example of a digital technology is the use of software to create a digital file (of how the design is), such as, dwg, dxf, stl, etc. Simulation is a digital file which accepts inputs to show how a part or assembly would react. Different definitions exist for a digital twin. Here, a digital twin is any virtual file that receives data from the physical part or assembly. It must be said that this is a simple interpretation of a digital twin and ignores higher levels of digital-physical feedback and control that are possible [15].

Table 2. Levels of digital teaching

	Design project or unit							
Digital twin	Engineering Experimentation unit				DfMA (BEng in Manufacturing only)			UWE
								Bath
Digital simulation					Systems design unit		Computation methods unit	UWE
					Sub-assembly design			Bath
Digital technology		D&M(I)	Engineering drawing(G)					UWE
		Engineering drawings (I)	Constrained design (I)	D&M (G)		Product design	Machine design (G)	Bath
	Y(0)	**S1**	**S2**		**S3**		**S4**	

3.2 Discussion

Table 2 shows that the design teaching at Bath uses mostly individual digital technologies. A driver for this structure is the layering up of skills as students' progress through the four units and cover the mechanical engineering design curriculum. The teaching focuses on design fundamentals across a range of projects enabling students on all programme's multiple experiences of the design process in a systematic way. The projects give students hands-on experience of using digital technologies in CAD and CADCAM, which also proves to be valuable on the placement year. However, with large class sizes, the open group assignment needs to be planned with technical staff to ensure the manufacture and assembly requirement does not exceed workshop capacity. The scale of the prototype needs to consider the number of parts students are likely to have in the assembly, to budget for the cost of bought-out parts, and to plan for in-university manufactured parts. The technical staff must also prepare orders for bought-out parts and materials acquisition from each group's bill of materials. The additional responsibility for the group's BoM and budget gives students a closer experience to mechanical engineering design practice in industry [16].

A numerical model is introduced in the first semester of Year 2 to form a simulation of how a part within a machine behaves when subject to compound loads. Further digital simulation, such as, FEA is taught in units other than design. However, the teaching does not extend to digital twins. As noted earlier, digital twin technology is in its infancy, so it is unsurprising it is not seen it in a traditional mechanical engineering degree. That is not to say that awareness of digital twins is not gained in the later optional units. If digital twins are to be taught as part of design teaching, then additional resource would be required to couple the digital simulation with the physical system.

At UWE, engineering drawing (2D and 3D) is learned in a group activity where students each draw a 3D part of an assembly which are then brought together to create a model of the assembly and animation for summative assessment. The 2D engineering drawings are completed throughout but as a non-assessed ongoing activity in which the benefit is in gaining drawing experience. The S1 D&M is individual here, digital technologies are employed to generate stl files for generating a 3D part. In S3, systems design is delivered in which students design a mechanical drive assembly, typically an actuator, gearbox and electric motor. In S4, students are taught digital simulation through computational methods units, by creating FEA and CFD models. In S1 and S2, the number of BEng students is in excess of 300 and they study the Engineering Practice (D&M and engineering drawings) in groups (e.g., tutorial class size 25/50) which ties up teaching resource even more. The D&M exercise is limited to students varying the geometry of one part. This also limits the resource needed to support the activity but does enable students experience of 3D printing parts to their variant design.

At UWE, the BEng degree programmes have a foundation year. In Year 0, is an Engineering Experimentation unit in which students use digital twin technology to gain an awareness of how to control a mobile case assembly production line. The production set-up consists of two assembly lines which are connected by a moving automatic vehicle, see figure 1. It has Siemens software for control (e.g., NX software) and Festo hardware (e.g., pneumatics) and cost in the region of £320K in 2021. This purchase is part of a Siemens Connected Curriculum which give access to their digital software. In this Cyberlab the virtual model is already generated and data-linked to the production line. The students appreciate how the digital twin reacts to the outputs from the physical space output, such as, the production line product flow.

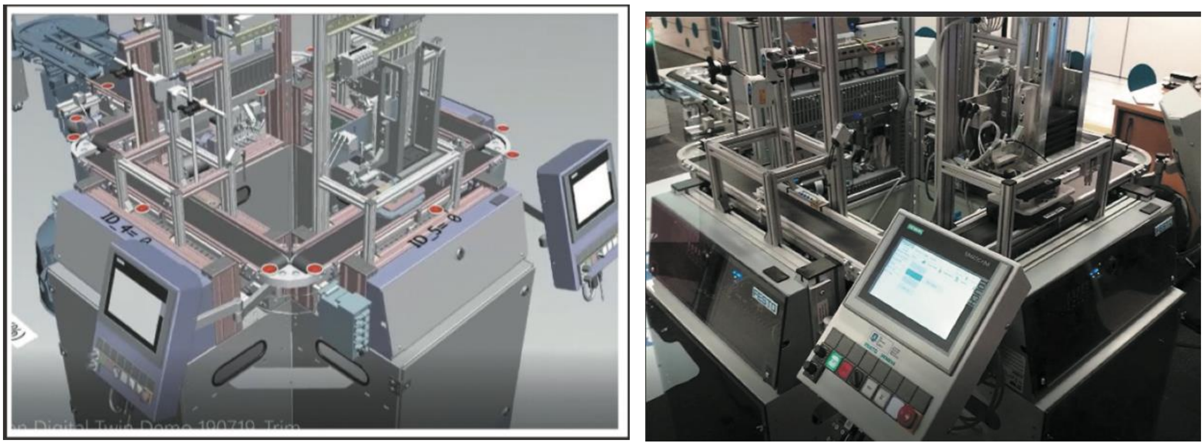

Figure 1. Siemens production line with (a) digital twin technology and (b) physical object

The Siemens Cyberlab is also used for Year 2 teaching, but only for students on the BEng in Manufacturing course. In the DfMA project, students create a manufacturing plan for the production line layout of the digital twin Cyberlab.

4 CONCLUSIONS

The digital environment, in which design teaching is delivered at UWE and Bath, is described in three levels: digital technology, digital simulation and digital twin. Both universities run multiple programmes that are combined to study the design units in a cohort size of over three hundred. To enable large cohorts to use digital technology in their design exercises, planning and technical support is required. In the case of the Design and Make exercise, UWE controls the support required by planning this exercise as a variant design. Here, each student uses digital technology to create a 3D model of a single part only, such as a jar clamp, and then generate an stl file from which the part is 3D printed. In contrast, Bath plans Design and Make as an open group exercise of a mechanical assembly, which needs considerable support from technical staff to procure and manufacture a high number of parts. Similar to UWE's students, Bath students use digital technology to create a 3D model of the assembly and where needed CAM files for 3D printing and laser cutting.

Digital simulation is taught by both universities to upskill students in the creation of FEA and CFD models. At Bath, digital simulation is not taught within the four design units, but by other units. However, in Bath's Design 3 unit, students write their own numerical model to simulate how a part reacts under loading. The idea of the Digital twin, shown in table 2, is introduced by UWE to all foundation year students as part of the Engineering Experimentation unit, in which students gain an awareness of an existing virtual-physical Siemens-Festo system.

The digital environment is predicted to grow significantly in the next decade. Presently, students are taught how to use digital technology to create CAD and CAM files of their designs making them effective in their placement roles. If industry continues to increase its use of digital twins, education may need to include it in the curriculum and deliver it by either creating its own digital twins or, in the case of UWE, decide to invest in an appropriate industrial package.

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AN ADVANCED MANUFACTURING SUPPORTED SUPPLY CHAIN – EDUCATIONAL CASE STUDIES

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ABSTRACT
This paper details the design process and analysis undertaken within the Royal National Lifeboat Institution (RNLI) to positively disrupt the supply chain using advanced manufacturing technologies, and then how this information has been utilised and adapted for teaching to product design and engineering students at Bournemouth University (BU) to consider in their future design work. Analysing engineering components alongside their supply chain data led to creating case studies which detail the benefits Additive Manufacturing (AM) could offer the RNLI. The aim of this research was to identify specific areas where additive manufacturing could be implemented into the engineering industry to have positive outcomes, such as cost and lead time savings, and then disseminate this real world manufacturing knowledge to design and engineering students. It was found that through redesigning two lifeboat components that reduced lead times, reduced cost, and reduced component weights could be achieved. These real world findings then led to informative case studies being developed to aid in the teaching of designing for additive manufacturing for product design students at Bournemouth University.

Keywords: Supply chain, additive manufacturing, advanced manufacturing, 3D printing, design, higher education

1 INTRODUCTION
The goal of traditional supply chain spare parts management is to maintain a minimum level of spare parts inventory whilst still being able to fulfil demand and maintain customer satisfaction. Optimising product flow and stock levels generally require transporting spare parts to the point of use from a centralised storage location [1]. While moving from a decentralised to a centralised network can lower costs and improve service performance it will have a negative impact on the environment due to the increase in transportation needs [2]. It has been recognised that Additive Manufacturing (AM) technologies have the potential to positively disrupt the supply chain by reducing the requirement to hold and transport stock, produce cost and lead time savings, while also guarding against supply chain disruption.

The Royal National Lifeboat Institution (RNLI) is a UK charity that saves lives at sea. Its headquarters is based in Poole, Dorset, UK and the institution has 238 lifeboat stations around the UK which currently require the delivery of stock on a regular basis. It opened its All-weather Lifeboat Centre (ALC) in 2015 where it now manufactures and maintains its fleet of 431 lifeboats. It was found that the current inventory level held by the RNLI at its headquarters has a value in excess of £20million, an average age of 13.85 years and a demand ratio of 1.84 [1]. This means that the RNLI holds nearly double the amount of stock, which is demanded each year, and on average a component ends up costing the RNLI 346% of the initial part cost once used. It was established that the RNLI holds excessive amounts of inventory because of a ‘just in case’ reasoning, which leads to expensive storage, transport and disposal costs, should any components become obsolete. Therefore, AM was investigated as a manufacturing technique for the RNLI in order to reduce the requirement to hold, move and dispose of the current costly and excessive inventory. The RNLI stated in their 2018 Annual Report and Accounts that this type of manufacturing would have a positive impact on their sustainability, in both financial and environmental terms [3]. The RNLI has committed to eliminating or reducing their negative impacts on the environment and to becoming a low-carbon, zero-waste-to-landfill and climate-resilient organisation in the future [4].

A project, providing academics and students with the opportunity to collaborate with the RNLI, was funded by Bournemouth University's (BU) allocation of Higher Education Innovation Funding (HEIF). HEIF is provided to support knowledge exchange between higher education providers and the wider world that benefits society and the economy. Key objectives of this project were to work with the RNLI to investigate the potential impact of introducing AM on their business while providing opportunities to enhance student learning. This article presents results of the findings of the project undertaken with the RNLI and then details how this information has been utilised and adapted for teaching to product design and engineering students.

2 RESEARCH METHOD

2.1 Literature Review

Literature surrounding the subject of additive manufacturing, and how it could positively disrupt supply chains across different business sectors analyses strategic investments in AM for the maritime industry, how it could be used and adopted, and is developing a mind-set for which organisations should follow to adopt to the technology [5], [6]. However, the literature also suggests that in order for the maritime industry to move forward with AM and the benefits it has to offer, real maritime case studies and experiences need to be generated [5], [6]. Current literature informed the research project as it enabled insight into how the maritime industry are adopting these technologies in different ways, further benefits that it has to offer the industry, and how this could potentially be applied to the RNLI.

2.2 Primary Research and Analysis

Supply chain data from cradle to grave was collected via meetings with key stakeholders within the organisation. The key stakeholders included the Procurement Manager, Warehouse Manager, Innovation Manager, Engineers, and Senior Engineers. A key starting point of the project involved working with a Senior Category Manager within the supply chain to understand where the research should focus to achieve strong outcomes. The RNLI categorises stock dependent on the speed that it moves through stores. From category 'A' being fast moving stock, through to category 'C' being slow moving stock. Through investigations with key stakeholders of the project it was decided that category 'C' components, and items with long lead times, could most benefit from the implementation of AM. These parameters were selected as these parts cause problems for the RNLI supply chain in terms of inventory management and unnecessary costs (high storage costs). Analysis was conducted on component data regarding lead times, costs, materials, and AM suitability. This led to several components being selected as suitable for this research study to show the benefits AM could offer the RNLI.

Two variations of AM were explored in the research. Both were different types of composite 3D printing as this would allow the RNLI to produce end use components fit for purpose when out at sea. Although both offer composite 3D printing, they do so in different ways. These are chopped strand composite printing, and continuous strand composite printing. Stratasys (Minnesota, US) offer a material called Nylon12CF, which is capable of being printed on their Fortus production systems. Nylon12CF is a Fused Deposition Modelling (FDM), carbon fibre (chopped strand) reinforced thermoplastic. The material properties of Nylon12CF include high strength-to-weight ratio as well as high tensile strength [7]. Markforged (Massachusetts, US) offer 3D printing in a combination of Onyx and continuous strands of reinforcing fibres. Onyx is Markforged nylon thermoplastic which is infused with chopped carbon fibre. The continuous reinforcing fibres then include; carbon fibre, fibreglass, high strength- high-temperature fibreglass and Kevlar. Markforged claim that Onyx material reinforced with carbon fibre is strong enough to replace aluminium at half the weight and can be used when superior stiffness and minimal deflection is required [8].

3 RESULTS AND DISCUSSION

The analysis of components, from a supply chain perspective, gave a number of components that would be suitable to perform in-depth research upon to demonstrate the advantages AM could offer the RNLI's supply chain. With supply chain (reduced lead time, reduced cost) and engineering benefits (weight reduction, corrosion resistance) in mind the list of suitable components was narrowed down to two. These specific components were chosen as they both sat in category C stock, meaning they were slow to move through the warehouse, but because of their long lead times the RNLI always had to keep several of them in stock 'just in case' they were urgently needed. These two specific components are the 'Mast Latch Handle' and the 'Sea Water Inlet Strainer'.

3.1 Mast Latch Handle

The mast latch handle is a part used on a Shannon lifeboat to lock the mast into position. The part is currently made from aluminium and is manufactured via a traditional subtractive technique (CNC mill) from stock material. The mass of this part is 0.182kg, its lead time is 28 days, and its cost is £221.91. Both variations of composite AM from Stratasys and Markforged were investigated in this case study. Machine information, printing parameters, and final component information can be found in Table 1:

Table 1. AM Mast Latch Handle Information

	Stratasys Component	**Markforged Component**
Part Fill	100% Solid Nylon12CF	Triangular Fill 37% - 13cm^3 Carbon Fibre Reinforcement
Print Time (hours)	1.48	7.20
Component Cost (£)	21.49	36.65
Component Mass (kg)	0.073	0.048
Parts per build plate	7 max	2 max (Mark Two)/ 4 max (X7)
Machine Cost (£)	58,000	11,995 (Mark Two)/ 52,672 (X7)

This data shows the benefits the additively manufactured composite components offer over the current aluminium part from a supply chain perspective in lead time, part cost, and mass reduction. To benefit from the component cost and print time provided above, purchasing a machine to have on site is required. The Stratasys Fortus 380mc Carbon Fibre edition is quoted as £58,800 (September 2019), the Markforged Mark Two desktop is quoted as £11,995 (September 2019), and the Markforged X7 is quoted as £52,672 (September 2019). As this is an engineering component it was vital to prove that the additively manufactured composite component would be able to perform comparatively to the aluminium one in service. After analysing how this component is used it was vital to conduct testing on the part which mimics what it is exposed to in real world situations. The main test conducted was a force/deflection test to analyse stiffness. This test was used to compare deflection that would occur when subjected to real world loading. This test was carried out on the aluminium part, the Stratasys Nylon12CF part and the Markforged part containing 13cm^3 of reinforcement. The force/deflection setup and test results can be seen in Figure 1.

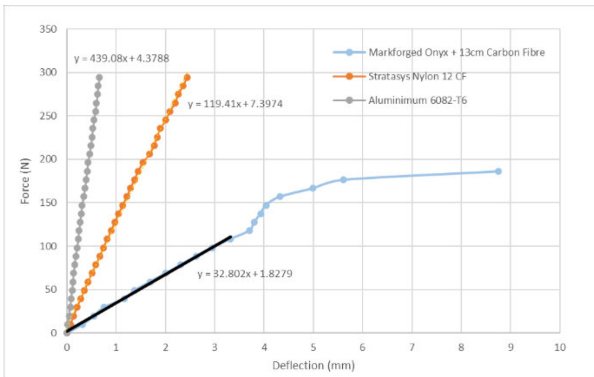
a)  b) 

Figure 1. Force/Deflection a) Test Set Up and b) Test Results

The results show the Markforged component with $13x10^{-6}m^3$ of carbon fibre reinforcement failed at 196.2N (20kg). The aluminium and Stratasys components did not fail when the maximum load of 294.3N (30kg) was applied. The stiffness of each part was determined by calculating the gradient of each force/deflection graph. For the aluminium and Stratasys parts, the stiffness was calculated from the complete data set. The stiffness of the Markforged component was calculated from the linear portion of the force deflection curve only as indicated by the solid black line. After a deflection of approximately 3.6mm, a large change in stiffness was observed due to carbon fibre reinforcement failure in the material decreasing the part's stiffness. The results in Figure 1b show that the aluminium had the highest stiffness (439.08N/mm), followed by the Stratasys Nylon12CF (119.41N/mm) and Markforged component

(32.80N/mm). The Markedforged component was determined as not suitable to replace the aluminium part as its strength and stiffness were too low.

The Stratasys Nylon12CF was determined to have the potential to replace the original aluminium part as it had a comparable strength. The stiffness was 3.7 times lower than for the aluminium part and further tests are required to ensure that the higher deformation of the Stratasys part would not impact on the operation of the latch handle. If found to have an impact on the operation, the part would be redesigned with thicker cross-sections to increase the stiffness. Even with increased thickness, the part's mass would still be lower than the aluminium part and costs to manufacture also less.

3.2 Sea Water Inlet Strainer

The 'Sea Water Inlet Strainer' is a component used on a variety of different lifeboat classes to stop debris from entering the engine cooling system. It is currently fabricated from a wrapped stainless-steel sheet and two stainless steel flanges either end. The mass of this component is 1.7kg, its lead time is 3-4 weeks, and its cost is £110. However, due to corrosion issues, the RNLI regularly replaces this part.

As the RNLI want small quantities of this component produced every year, injection moulding was not a viable option. The RNLI engineering team previously considered additive manufacturing as a suitable production method for this component and sent it, in its current form, to 3D printing bureaus for a quote. These quotes came back in excess of £800 per component. This was due to the part not being designed for the AM process. A common misconception of additive manufacturing is that an existing component which has been designed for another method of manufacture can be additively manufactured in its current state. This is of course possible, but by no means gives the best results additive manufacturing has to offer. The original design of the strainer, running it through GrabCAD (Massachusetts, US) slicing software, would require each circular hole to have support material running all the way through. Support material had to run the whole height of the part, and thickness of the overhang to be able to print the top flange. This resulted in a volume of model material of $278 \times 10^{-6} m^3$ and support material of $893 \times 10^{-6} m^3$. The cost of this volume of material in Stratasys ABS-M30 would be £350.

Designing for additive manufacturing is a vital step to achieving the most out of the process. The design changes that were made to this component for additive manufacturing were (Figure 2):

- Increased wall thickness, as the current thickness had been designed for stainless steel so to make sure the ABS part would provide the required impact strength this had to be increased.
- Circular holes were changed to diamond shaped holes. The diamond shape is self-supporting as the next layer never goes over a 45degree overhang to the layer below reducing the requirement for support material.
- The top flange was separated, a lip and groove added to the CAD model, printed separately and then chemically bonded together afterwards.

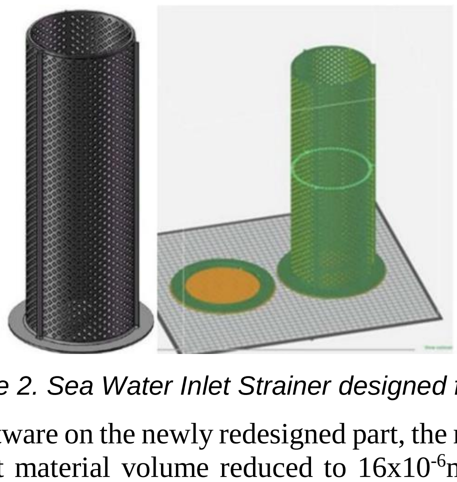


Figure 2. Sea Water Inlet Strainer designed for AM

Using the GrabCAD slicing software on the newly redesigned part, the model material volume increased to $543 \times 10^{-6} m^3$, and the support material volume reduced to $16 \times 10^{-6} m^3$ costing £160 in Acrylonitrile butadiene styrene (ABS). After re-designing this part specifically for additive manufacturing, the new component mass is 0.526kg, new lead time is 3 days, and the new cost is £160. These comparisons show that the AM part in this case is more expensive than the original. However, the AM part will not suffer corrosion problems and will not have to be replaced on a yearly basis, therefore making it more cost effective. To fully validate the AM part, Charpy testing of the impact strength would be required.

4 STUDENT LEARNING

After the research project had provided successful results for using additive manufacturing within the RNLI, the findings were utilised in teaching level 5 (second year) students studying BSc/BA/MDes (Hons) Product Design. To effectively communicate to students the relevant research findings and how they can be utilised within the design and engineering industry, the research results were presented to design and engineering companies and qualitative data was gathered through a questionnaire (Table 2). This data informed what knowledge industry already had regarding designing for additive manufacturing, and highlighted gaps in their knowledge. This guided the dissemination of knowledge to the level 5 programmes, so they were up to date with current industry knowledge and also take new, valuable knowledge into industry with them. The main findings to impart was how additive manufacturing could be used within the design and engineering industry to achieve a streamlined supply chain, offer freedom within design, end use component production, and its impact on lifecycle sustainability, using real-world case studies.

Table 2. Questionnaire results from Industry Dissemination

	Strongly Disagree	Disagree	Neutral / NA	Agree	Strongly Agree
Has your knowledge regarding AM benefits for industrial applications increased from these research findings?	0	0	0	22	12
Has your knowledge regarding designing specifically for the AM manufacturing process increased from these research findings?	0	1	8	17	8
Is your business more likely to investigate the use of AM following these research findings?	0	0	10	15	9

A lecture was delivered to over 80 product design students, to disseminate the research findings and processes. This was an opportunity to give students an insight into both research and enterprise work, and industry practices. Challenges in delivering this research and case studies included how to breakdown over a years' worth of highly detailed research into a one-hour lecture for students who had very little prior experience to industry and research. Denicolo and Becker [9] believe that a good lecture allows students to 'see the results of your research in action', 'be inspired by your enthusiasm', and 'ask you questions'. Therefore, the lecture contained aspects of the research that matched with the unit learning outcomes [10], aspects which were interesting within design for additive manufacturing, so enthusiasm would engage the students, and then also provided a period of time for questions. The lecture centred around the technology used in the research study, as it is technology the students have access to within the university for their upcoming projects, the process of designing for additive manufacturing, and the final outcomes achieved. One of the main purposes of disseminating the research findings to the students was so they could take the knowledge forward and apply it into their upcoming additive manufacturing technology project.

The lecture began with an overview of the clear methodology used throughout the research. This gave the students information from the beginning of the lecture which engaged them and allowed them to understand the process of the research study and not be overwhelmed by the information that would be delivered. The lecture went on to disseminate information regarding the technology investigated in the research, testing and analysis conducted on a variety of case studies, and then final outcomes achieved. To ensure the students would interact with the lecture and take information away from the case studies which they could later apply to their own design for additive manufacturing work, the lecture was interactive and designed to suit a variety of different learning styles. The learning styles included visual, audio and kinaesthetic learners [9], therefore the lecture integrated talking, part demonstrations, images and videos. Videos used in the lecture included showing the process of additively manufacturing parts and then the testing conducted. These videos helped visual learners to further understand the technological processes that were being spoken about during the lecture. Part demonstrations involved taking AM parts from the project into the lecture and allowing the students to pass them around, have hands-on experience, and have discussions about the parts designs and manufacturing techniques, therefore getting the students engaged in the lecture. The mixture of approaches worked well, and received good student feedback, as it constantly kept the students engaged and interested as they had opportunities to talk and discuss the demonstrations amongst themselves then regroup and take in the next lot of information from the lecture. It enabled discussions, questions, and thoughts which otherwise would not have happened. This lecture regarding the research and enterprise work undertaken within the RNLI delivered many positive outcomes, including engaging students, disseminating knowledge and answering questions that students had, this was evident from student participation during the session, the information they carried forward and used in their subsequent additive manufacturing project, and student feedback received.

To follow up and support the dissemination of this research to the product design students, and so they had an opportunity to put their understanding into practice, a subsequent lab session to bring students into the Rapid Prototyping facility at BU was undertaken to physically show them the machines used in the project, show them the processes used to design the parts for additive manufacturing and then a project was set to them to redesign a part for additive manufacturing. This gave them an opportunity to use their skills for designing for additive manufacturing, use the 3D printers, and conduct the post processing that follows so they could have first-hand experience of the whole process. Outputs from this project saw students using topology optimisation to redesign components on a motorbike frame, resulting in lower weight components that could be additively manufactured. This is important as it puts into practice what the students have learnt, offers different learning styles the opportunity to thrive, and gives an opportunity to assess if the learning outcomes of the lecture have been achieved based on what they can do after the learning experience that they could not do before [11].

5 CONCLUSIONS

The findings from this research have been beneficial to both the RNLI, BU staff and the product design students. Knowledge transfer has taken place, benefiting all parties. The benefits that AM could provide the RNLI supply chain and its engineering department have clearly been identified. The students involved have been given real world case studies on how additive manufacturing is being used within the design and engineering industry, enabling them to apply what they have learnt to subsequent assignments.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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A CRITICAL CURATION OF SOLUTION REPERTOIRE BY FIRST TIME DESIGN STUDENTS

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ABSTRACT
Design education has a nuanced relationship with examples. Although they are considered useful teaching tools, their use is often restricted to illustrating the design theories and principles around which the curriculum is structured. In contrast, professional designers view examples as autonomous entities and use them to initiate a critical dialogue with their current problem space. Therefore, students should be facilitated in cultivating their own repertoire of solutions and learn to initiate conversations between existing solutions and design challenges to gain a better understanding of the problem space and generate new designs. This paper outlines a small-scale experiment conducted with master's students in Applied Data Science at Utrecht University who took a course on designing recommender system interfaces. The students were provided with a set of examples of recommender interface designs as their main instructional tool. They could use this set to curate their own solution repertoire. As a result, the majority of the participants' work displayed more diverse designs, and they used design patterns distilled from those examples generatively, developing innovative designs. Based on this case study, we tentatively conclude that a design curriculum built around examples, complemented by theories, could be advantageous, as long as special attention is given to helping students initiate fruitful iterations between their challenges and a set of solutions.

Keywords: Solution repertoire, professional practice, problem space, exemplars, curriculum design

1 INTRODUCTION
Studies on design practices over the past half century consistently show that designers tend to approach design challenges with a solution-oriented mindset [1–8]. They engage in reflective conversations with their design challenge and use existing solutions or precedents as conversation starters[2, 7]. Dorst & Cross, for instance, noted that designers iteratively evaluate and appreciate existing solutions within their specific challenge, enhancing their understanding of the problem space with each consideration [3, 9].

That is in contrast with how design curricula within HCI are generally organized [7, 10]. Currently they tend to emphasize high-level conceptual knowledge, supported by intermediate knowledge such as design heuristics [3], design patterns [4], strong concepts [5], or annotated portfolios [6]. Examples used in these curricula are exclusively tied to high-level or mid-level knowledge. For instance, topics covered in HCI courses typically include Nielsen's heuristics, user research, creating a user journey, persona's, human-AI interaction, etc. [11], rather than examples of specific interfaces such as Netflix, OkCupid, Waves, or Roblox. High-level and intermediate knowledge are considered generative design tools, while examples serve as illustrations of these principles [9]. In order for design curricula to align more closely with professional practice, greater emphasis should be placed on actively and consciously building students' collection of precedents or a 'solution repertoire' [9]. This would help students develop skills to facilitate conversations between their repertoire of precedents and the design challenges they encounter.

This paper reports the results of a small-scale experiment conducted in the Covid'19-winter of 2021 with 37 master's students in Applied Data Science at Utrecht University. It aimed to recreate the solution-oriented professional practice by structuring part of the design course around a set of precedents. After briefly reviewing the status of exemplars as a form of knowledge in design curricula, we describe the experiment and provide a preliminary analysis of the results.

2 THE STATUS OF EXAMPLES IN DESIGN CURRICULA

Back in 1982 already, Cross has stated that design examples in and of themselves should be considered autonomous knowledge entities [12]. Structuring design curricula around design theories, in which examples function as illustrations, is, therefore, problematic for various reasons. Firstly, it implies that examples are determined by higher types of knowledge: the example is the way it is because of this principle. However, design examples can and should be viewed through multiple theoretical lenses [9], and tend, in fact, to be 'underdetermined' by theory [13]. Secondly, it prevents students from building their own conceptual network of examples, since the examples are taught in the context of specific theories, and, as a result, they will be mainly accessible through those theories rather than individually and interrelatedly [9].

Finally, and most importantly, denying examples a status in their own right does not echo the actual design practice. As Boling and Gray show, students will use precedents, whether they are aware of it or not [7]. If they are not taught to use those precedents consciously, and consider them properly and critically, their resulting designs will suffer.

Van Turnhout & Smits, therefore, introduce the concept of 'solution repertoire' as a founding principle for design curricula. They define 'solution repertoire' as "the competence of appreciating and handling solutions in one's design discipline and to use them as an anchor point for design-relevant knowledge that goes beyond the anecdotal experience" [9]. In this approach, a solution repertoire is a performative concept: students build their own repertoire, carefully curated from formally or informally encountered, and self-designed precedents. A design curriculum could then be organized as in Figure 1:

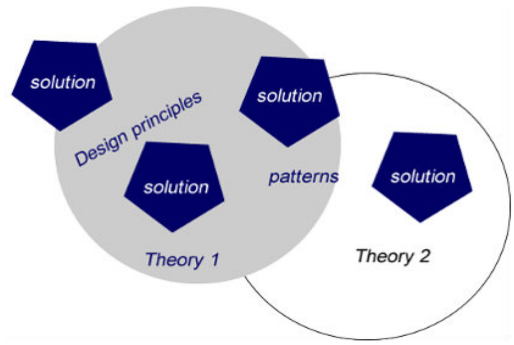

Figure 1. A curriculum design organized around examples or solutions

In this organization, solutions are the central elements that connect sets of abstract knowledge, and the various theoretical lenses serve as means to analyse the examples from different perspectives. Solutions are in this vision the foundational blocks of the curriculum. This curriculum structure is geared towards helping students curate a solution repertoire and support their skills of critical analysis of examples in specific contexts. It does, however, not imply there is no place for design theory and design principles. It just means that those are not the structuring elements of a curriculum; rather they take the auxiliary position that was earlier reserved for the examples.

3 EXPERIMENTS: A SOLUTION REPERTOIRE-BASED DESIGN CURRICULUM

In de winter of 2021, our design research group Human Experience & Media Design (HEMD) and our teaching staff at the Master Data-driven Design [14] were asked to provide a course on interface design of recommender systems for 37 master's students in Applied Data Science at Utrecht University with little to no prior experience with interface design.

This course provided an opportunity to experiment with the notion of examples as an organizing principle in this curriculum. Our main instructional tool was, therefore, a set of examples of recommender interface designs. An inclusion criterion for this set was that they all had to contain some form of 'algorithmic affordance', that is: they all had to provide their users with "interaction options that give tangible control over the algorithm" [15]. During the classes, the examples were examined through various lenses, such as the theory of value sensitive design [16], human-centred design, and the design of human-ai-interaction (see Figure 2).

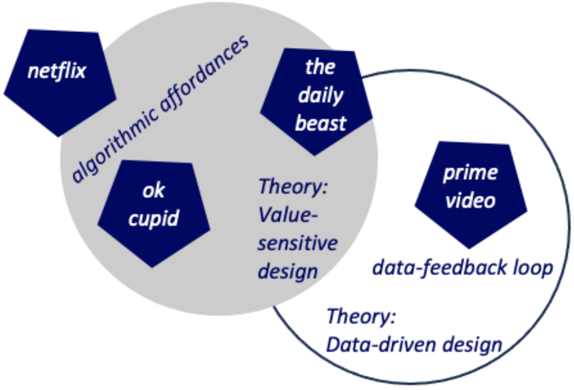

Figure 2. Part of the recommender interface design curriculum structure

In phase 1 of this experiment, we first assigned the students the task of designing 'an interface' for 'a streaming service', just to explore options and get familiar with the practice of constructing interfaces in general. At that time no precedents had been provided yet, nor had the general idea of designing with precedents as (generative) design tools been discussed. In phase 2, however, students were provided with precedents, as well as with explicit and implicit instructions to consider precedents carefully and to curate their own set of precedents. In this phase, the assignment was again to design a recommender interface for a streaming service, but this time for a specific user group that students had selected themselves. The interface had to include algorithmic affordances and therefore, it had to provide users with control. From their user research, students distilled values that were relevant to their selected user group and those values were to drive the types of control that would be implemented in the interface. The students' final interface design had to be accompanied by a document in which they had to reflect on their consideration of various exemplars and how they did or did not use them to build upon them. The reflection documents were analysed by the teaching staff, based on the assessment criteria formulated in the assignment. Relevant statements were highlighted during grading and later analysed for generative power. Statements that were included were for instance 'I considered Tinder's interface and decided, you could use such a one-by-one judgment for movies, too. The selection process would then be slower, but at the same time, every next movie would be a better match, rather than having to plough through 20 irrelevant movies' (S6). This was considered a generative statement.

4 RESULTS AND DISCUSSION

The students' work on these two assignments led to three main conclusions. Firstly, we established again that, designers (experienced or not) use precedents as a starting point. Most of the results of the assignment in phase 1, in which they had to design an interface for a streaming service, showed an uncanny resemblance to Netflix's, Audible's and HBO's interfaces (see and in a variety of contexts of use. They were clearly not viewed as illustrations of 'just that value', 'in just that context', for 'just that feature/use'. In one design, the algorithmic affordance of the 'data toggle'.).

Table 1. Traces of exemplars in assignment 1

26 assignments	- literal traces of Netflix/Prime Video-type of services
3 assignments	- literal traces of Netflix/Prime Video-type of services - generative traces of Netflix/Prime Video-type of services
5 assignments	- literal traces of Netflix/Prime Video-type of services - traces of social media interfaces (sharing, commenting, tagging)
2 assignments	- literal traces of Netflix/Prime Video-type of services - generative traces of Netflix/Prime Video-type of services (e.g., using profiles differently) - generative traces of social media (sharing, commenting, tagging)
1 assignment	- literal traces of Netflix/Prime Video-type of services - generative trace of social media (sharing, commenting, tagging) - generative trace of another online service (Tinder's judging

	recommendations one-by-one)

Consciously or not, students had used clearly recognizable examples as their starting points for their assignment and had implemented literal traces in their designs. In this study, literal traces are conscious or unconscious copies from existing examples: similar feature, similarly implemented, similar context-of-use. Generative traces are elements that have a similar use but are implemented differently in the student's design (for instance, rating is a sliding scale rather than a set of five stars), or that are used differently (for instance, rating implemented as blacklisting rather than supporting provided recommendations). Elements transferred from another context, such as social media (tagging other viewers) or dating sites (such as the Tinder-like judging of each individual movie) were in this study also considered generative traces, even when the implementation was similar.

For the assignment in phase 2, we observed an expected improvement in designer skills (simply because it was their second assignment). More importantly, however, and this is the second conclusion, for a majority of the students we could also establish they had actually used examples as generative design tools, resulting in their own original designs. Examples of similar algorithmic affordances were used to implement a variety of values, for different target groups and in a variety of contexts of use. They were clearly not viewed as illustrations of 'just that value', 'in just that context', for 'just that feature/use'. In one design, the algorithmic affordance of the 'data toggle'. In one design, the algorithmic affordance of the 'data toggle' was, for instance, used to allow users to see explanations for their recommendations, facilitating the values of diversity and transparency (see Figure 3a), while in another design the same example of the data toggle was used to implement transparency again but in this case also to tune the algorithm, weigh parameters differently, and consequently, adapt results (see Figure 3b). In sum, more students had started to use examples in a generative manner.

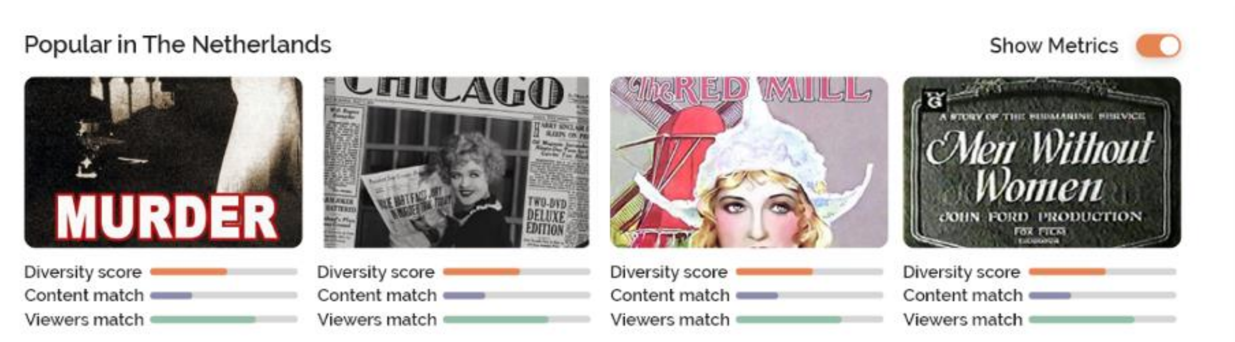

Figure 3a. Toggling explanations for recommendations

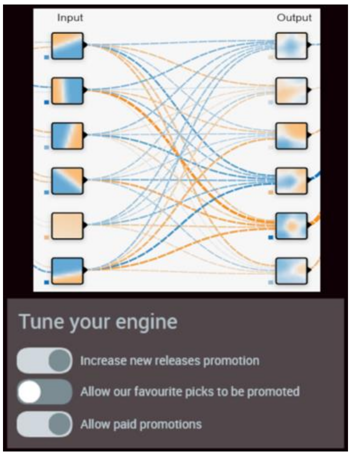

Figure 3b. Toggling explanations for recommendations

The solution repertoire also triggered students into developing their own variations and innovations. Figure 3a is already an innovative example of how explanations of recommendations can be visualized, by the student's own admission, for "people who are as techy and nerdy as I am" (S12) [17]. The diagram in this figure visualizes how the recommender settles on specific output, and to what extent diverse input sources (previously watched movies, paid promotions of the company, user similarity, etc.) contributed to that output. Transparency is here implemented by visualizing decision paths, an example that was present in the provided solution repertoire. The final design, however, implements such a decision path in a completely different way, developed by the student himself. Figure 4 presents a last illustration of generative designs inspired by precedents. This student was triggered by examples of building different profiles. Rather than profiles for individual users, however, they created contextual profiles and made recommendations for 'Lazy Sundays' and 'Fridays with friends'.

In their reflection documents, 23 out of 37 students clearly show how they had taken their target groups' values as a starting point ('their problem space') and had subsequently browsed the solution repertoire to see if and how any of the solutions would help them implement those values ('critical conversations between precedents and problem space'). They then selected examples that were helpful and transformed them into a solution that worked in their own design ('creating a new design'). S11, the creator of the example in Figure 4, for instance, stated "I liked the idea of contexts, but not of tying it to a person; for my target group social watching is more important than defining them as individuals".

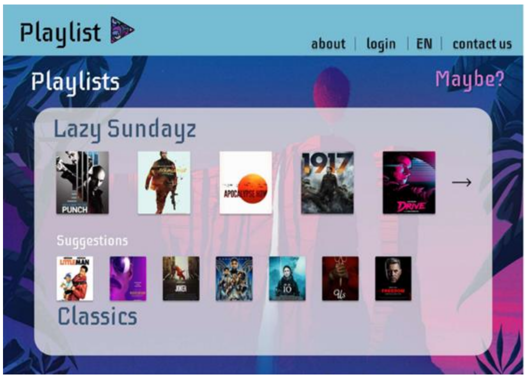

Figure 4. Newly designed means of profile creation

However, this process was not as smooth for the entire student population. As a third conclusion we found that a significant minority of students (14) did copiously use the solution repertoire, but still not critically. Rather, these students seemed to consider the set of exemplars more of a list of ingredients that all needed to be integrated in their assignment, resulting in an unbalanced mix of solutions. See Figure 5 for an example of an unbalanced interface aimed at 6–10-year-olds, that displays no critical appreciation of the various elements:

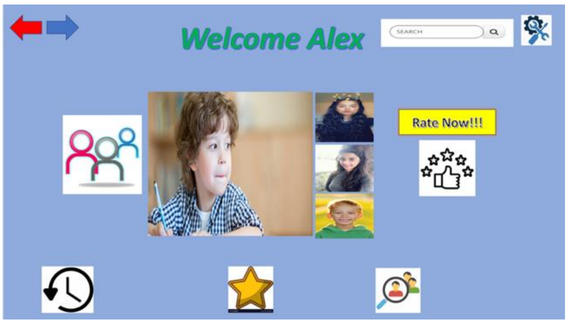

Figure 5. An unbalanced combinations of examples

In the discussion following the hand-in of their work, the creator of this work stated, "I am just learning to speak 'design'; I did not know what to do with those examples and thought I had to use something from all of them, to show I had looked at them" (S24). In short, they considered the examples prescriptive rather than inspirational. Crucial for a curriculum centred around examples, therefore, is to make sure the examples do not attain such a status that students feel they *cannot* be changed and *have* to be used.

5 CONCLUSION AND LIMITATIONS

Based on the results of this experiment, we tentatively conclude that it is beneficial for design curricula to explore constructing their curriculum around examples, allowing students to build their own solution repertoire. This small-scale and admittedly limited study shows that providing exemplars in a design curriculum as autonomous entities rather than as auxiliaries to higher concepts can support examples' generative power for new and innovative designs. However, teaching the skill of critical appreciation and evaluation, and having students experience how those conversations enhance their understanding of their problem space is an essential for this approach. That should help give students the confidence that they 'speak enough design' (academic integration into the domain) to employ their repertoire to the fullest and allow them to challenge design contexts and generate their own innovative designs.

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ETHICS IN DESIGN EDUCATION, BUT COMPLETELY DIFFERENT: TEACHING THROUGH INTERACTIVE INSTALLATIONS

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ABSTRACT
In a collaboration between the University of Twente and the Saxion University of Applied Sciences ethics education is explored from a tool-based, practical perspective. In this ongoing project the focus lies on the question if and how practical tools for ethical deliberation can be helpful in ethics education for engineering students. To adhere to the practical perspective, the approach uses a focus on the impact of technology as a way toward ethical deliberation. The idea is that engineering students should actively take the probable, desirable, *and* possibly unwanted effects of their designs into account *during* the development of their projects. To foster this process, we have the desire to build an ethics lab, analogous to an engineering lab or a design studio. As part of this ethics lab two students of the bachelor Creative Technology have designed an interactive installation to let the visitors of this lab experience classical ethical dilemmas in a contemporary manner. This paper will present the installations -representing Plato's cave and the Panopticon- as well as some preliminary experiences with "teaching ethics through interactive installations".

Keywords: Ethics of technology, reflective skills, ethics lab, interactive installations

1 INTRODUCTION
Designers have social responsibility by the very nature of their activities: bringing new products and services into the world of the user [1]. This responsibility calls for ethical awareness in the practice of design, as designers will be inevitably influencing the context of people and society for better or worse. Different approaches for reaching this ethical awareness have been developed, rooting in professional values [2] or on the other end personal ethics [3], ranging from teaching abstract ethical theories to analysing practical implications [4]. In an ongoing research collaboration between the Saxion University of Applied sciences and the University of Twente, the approach towards ethics education is from a tool-based, practical perspective [5]. Therefore, insights from design research are combined with philosophical theories [6 , 7] and the focus lies on analysing and exploring the impacts of new technologies as a way toward ethical deliberation [8]. In the initial phase, the study focused on the experimentation with this practical approach in a series of workshops with designers, design educators, and students [9]. From organizing these workshops, we came to the idea that there might be some environment that is especially suited for these kinds of workshops. Think of a dedicated space that stimulates ethical deliberation, just like a design lab [10] or studio environment can stimulate creativity [11].
Although at this point it is not yet clear how such an environment should look like, we started with the first elements that could be part of such an ethics lab. One of this is the envisioning of a 'canon of classic ethical dilemmas' to teach and inspire all people that will be visiting the lab. A small 'museum' to engage and confront users of the lab with ethical theories that they can refer to when reflecting on their own work. From this idea an initial set of two interactive installations has been developed, based on the respective ethical theories of Plato's cave and the Panopticon. The installations were each designed and prototyped by a Creative Technology engineering student in their bachelor graduation assignment.
In this paper we will present the theoretical backgrounds of our concept, the interactive installations itself, as well as the first experiences with exposing users to the installations.

2 ETHICS TEACHING AND DESIGN

In the first phase of the research project, experiences of consulted students and teachers indicated that practical tools for ethical deliberation are most valuable, provided that they are linked to explicit learning goals [5]. In the second phase, efforts are being made to (further) develop and test a suite of activating working methods to achieve these learning goals. The aim is to develop a package of teaching materials, together with the various engineering programs, consisting of concrete ethical exercises and assignments that can be used as a continuous learning line during the entire curriculum [12]. In the project we have identified four important ingredients for such exercises and assignments; 1) an ambivalent (or controversial) technology; 2) an application close-by (or appealing to the interests of the participants); 3) a concrete (design) activity and 4) the ‘right’ questions to ask. These ingredients should allow for effective learning experiences, especially with lecturers of engineering subjects that are themselves not trained as ethicists.

The next step in facilitating this ethical deliberation among practicing students is creating an environment that is inviting to do so. The idea is to make a dedicated lecture room where student groups and lecturers can come to do the workshops that have been developed within the project. This might also coincide with working on their own design projects. The setup of the room should then be stimulating, confronting, disturbing or at least inviting for discussion about the ethical aspects of the technology at hand. The first ideas for such an inviting environment ranged from “just a creative design studio setting” to a “privacy violating technologies Luna Park”. The rationale behind the latter was to let people experience negative consequences themselves in various ways, with the intention to make them more sensitive to potential unwanted side-effects [13]. Think of an entrance where half of the visitors is (randomly) excluded after being scanned with face recognition software, so they can feel how it is to be rejected by technology based on unknown parameters (“computer says no”). Although the effectivity (let alone the ethical practicalities) of this kind of ideas is arguable, it sparked the starting point of using interactive installations in the prospective lab to educate about classic ethical principles. Practically, the installations should introduce students and staff to complex ethical dilemmas and allow them to grapple with issues that arise from understanding ethical issues, and subsequently aid them in considering how their projects might affect the world [14]. Optimistically, they could also present “the individual as an agent of positive social change, capable of affecting both local and global communities” [15, p.86] through ethics education and confrontation [16].

For the design and realisation of the interactive installations we recruited bachelor graduation students from Creative Technology, a programme that educates for developing new and innovative products, applications and services building on Information and Communication Technology. The design material that these students are taught is ranging from new media to smart technology, using videos and sound, internet, all kinds of programmable platforms, sensors and actuators [17]. Which make them fitting for our task [18].

3 CLASSIC ETHICAL THEORIES

For the ethics lab a list was composed of possible classical ethical principles to present. This could be for instance the Chinese Room by John Searle, the Turing Test, the Trolley Dilemma, or the Veil of Ignorance by John Rawls. The students eventually chose to start with the Panopticon by Jeremy Bentham and Plato’s Cave as the central themes for their respective installations.

The Panopticon refers to the design of a circular prison, originating from the 18th century. The design presents prison cells with glass walls arranged in a circular manner around a central guard tower. This design allowed prison staff to individually observe each cell at all times, without the prisoners being able to tell if and when they were being watched. This concept of continuous surveillance would through Bentham’s theory lead to imprisoned individuals practising self-discipline, as they might be observed at any time [16]. This principle, labelled ‘Panopticism’ by Foucault is strongly connected to the loss of privacy in today’s communication society. On the other side of the spectrum, it is also used in the entertainment industry in television formats like Big Brother or the 1998 movie The Truman Show.

Even more classic than the Panopticon is the most famous theory by Plato, written around 380 Before Christ: The Allegory of the Cave. This theory is about prisoners chained down in a cave. They have been in that cave for their whole life, and they have been tied down and their heads are stuck in one direction, so they are unable to look around. Behind them is a fire and puppeteers that hold objects over a screen so that their shadows from the fire are cast on the cave's wall. Because the prisoners have never been in the outside world but have only seen the shadows on the wall, they preserve these shadows as the “reality”. They believe the shadows of objects cast by the moving figures are real things - and the only things. If a prisoner would escape from the cave, their eyes would hurt from the daylight and therefore, they would want to look back at the shadows on the wall again. Only after some time, they would be able to see anything from the outside world, let alone accept it as real. The allegory is about the perception of reality and Plato’s idea is that the world we perceive as humans is only a dim representation of the real world [19]. Students that in this project were interviewed about ethics education and the allegory by Plato made the connection to social media. Some of them were aware that not all information is true, and one mostly sees the “shadows on the wall” and not the actual reality. One participant made the connection with the corona pandemic, where a lot of (conspiracy) theories about the coronavirus came to light. She said that there were people who thought that they had seen the ‘real world’ and found out that the vaccination was not good for humans. “Maybe they escaped from the cave and we are just seeing the shadows” [20, p.25].

4 INTERACTIVE INSTALLATIONS

The principle of the Panopticon and Plato’s cave were translated into physical installations, where for both principles a contemporary element was added to appeal to the target group and emphasise the relevance of the principles for todays practice [16 , 20].

4.1 The Panopticon

For the Panopticon installation the chosen contemporary element was CCTV camera’s, Social Media, and surveillance technology. To emphasise the link with the original prison design by Bentham, the installation was designed to fully immerse the head of the user in a box-like shape, supported by a foundation styled as prison bars. Inside the box the user is entirely surrounded by displays, showing a large number of different video clips that should represent CCTV footage (figure 1).

Figure 1. Interactive installation based on Panopticism, developed by Tale Nap. From left to right: the physical installation, the imagery displayed on the screens inside, and a screen capture of the confrontation phase [16]

The user can interact with the installation by requesting to zoom in onto a specific video clip. After several rounds the user is shown a video of themselves instead of the requested video clip. This unexpected confrontation with the effect of being watched should evoke reflection on the concepts of privacy and surveillance, and of course also one’s own role in this when watching others on social media.

4.2 Plato’s Cave

The allegory of Plato’s cave was chosen to be explained with the contemporary issue of propaganda and ‘fake news’. To make the concept more relatable with the original theory by Plato, the installation was shaped like a cave. Projections, representing the shadows of the original theory were provided by a beamer from the outside. The cave itself was realized as a small tent, made from white cloth. Ultrasonic distance sensors and a small camera register the interactions with the user (figure 2).

The interaction flow of the cave-experience is based on social media posts and propaganda. Egypt was chosen as the central topic as it is well-known for its tourist attractions. However, at the moment it is also an unstable country with a repressive regime. To achieve this, the design creates an Egyptian feeling for the user, while still representing a cave. This is done by using some stereotypical characteristics of Egypt such as the desert, Pyramids, and Egyptian-style music.

Figure 2. Interactive installation based on Plato's cave, developed by Madee Schreurs. From left to right; two images of the cave-tent with projected footage and the sensors and camera on the inside [20]

The installation will start with a projected cave entrance which the user has to enter. An instruction text is displayed with explanation to the user on how to interact with the experience. The user will then be placed in a desert surrounding with all objects black, so that only the silhouettes of the objects are visible representing the shadows of the original allegory (Figure 3). Then the user should answer questions about Egypt, which will be displayed on the left side of the cave. During this process the user is framed with sunny social media posts and positive news articles from the Egyptian government. While the user is working on the question on the left, news articles with a less positive perspective on Egypt will be displayed on the right, unnoticed by the user. After answering all the questions, the user is asked whether they would recommend Egypt as a holiday destination. In the confrontation phase the installation will then reveal the one-sidedness of the news that was presented [20].

Figure 3. Interaction flow of the cave installation and an image of the projected footage, with social media post and silhouette of Egypt representing the shadows from the allegory [20]

The user is confronted with their own image taken by the camera, looking to the left while all the negative news was openly projected behind them (Figure 4). After some preliminary user testing the interaction flow with questions and answers was set to a duration of approximately five minutes.

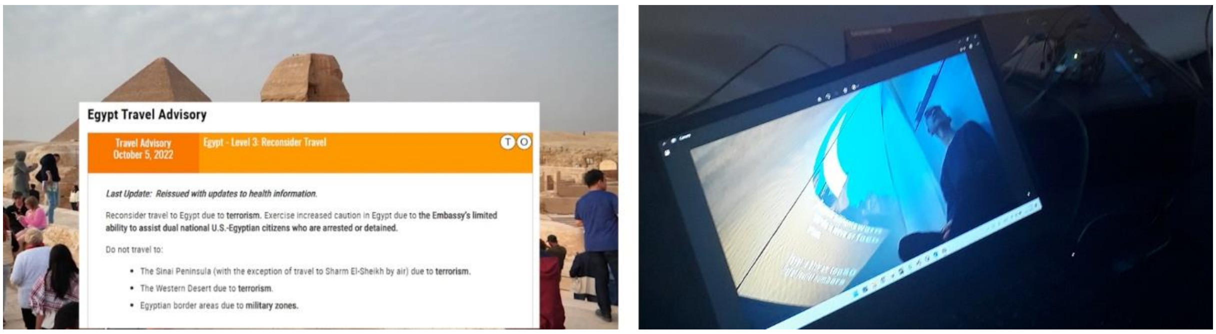

Figure 4. Objective information (left) is presented openly, however unnoticed by the user whose attention is effectively attracted to the other side (right)

5 EVALUATION AND DISCUSSION

The two installations were prototyped and put together on location in an office of the University of Applied Sciences. Then several students from the intended target group were invited to experience the interactive installations. With the Panopticon installation, the participants were interviewed before and after the experience in order to investigate the effect of being exposed to the installation [16]. With the Cave, the participants had no information about the goal and usage of the installation beforehand, so the participant would not be biased. This was also done to test whether the installation could be used independently, without the need for a supervisor in the lab [20].

Four students evaluated the Panopticon installation. They answered the interview questions, engaged in the installation and were interviewed again separately. After that they were invited to react on each other's answer and discuss the topics that were elicited by the experience together. In the starting interviews the participants noted the importance of ethics when pertaining to stakeholders and when approving research procedures. They also identified that ethics and technology were closely related, however noted few positive experiences with ethics education. The participants expressed interest in ethics education, however reported a lack of practical application of the methods and concepts discussed. All participants noted that the interactive phase of the experience felt quite normal. They generally understood that they were essentially unobstructed observing personal data from varying places around the world, however they equated this with scrolling on social media. Each participant also noted that being exposed to your own image during the confrontation phase harboured uncomfortable emotions. In the following discussion, the participants agreed that such an experience would give an individual additional insights on ethical concepts and topics. As one participant put it: "through this installation, the awareness comes very easily because all of the sudden it applies to you specifically. And that's very different from just reading about it or finding a case study" [16, p.61].

The five people experiencing the Cave installation were successfully framed into believing that Egypt was a pretty nice country [20, p.47]. In the end, when each participant was confronted with many more negative facts about Egypt, this created a realization that they had fallen for the one-sided news that was presented to them as "shadows of reality". People had experienced that by only seeing the shadows on the wall, the reality that they created for themselves might not be the actual truth. However, they also stated that they would not change their behaviour afterwards. Which is actually what Plato predicted. If people have never seen something else in their whole life, it is hard to accept a different reality [20].

The realized installations were thus able to deliver what they were supposed to do; engage the audience in ethical deliberation and connecting classic ethical theory to contemporary (design) practice. Although the initial evaluation only consisted of very few participants, it showed the potential of this type of interactive experiences for the initial idea of a dedicated educational space for ethics; that a specific physical environment can stimulate ethical deliberation in the target group. The next step will be to incorporate the installations in an actual educational setting with more students and staff. For now, the question remains how the installations will perform when teaching a complete class of students, or how they will be influencing a dedicated workshop. And how can it support group work within a technology oriented design project? In the current setting, each user has to individually engage with the installations. Especially with the Cave experience, which lasts for at least five minutes, it is not practical to teach large classes. Moreover, in the evaluation the participants even indicated that they would prefer an even longer duration of the specific experience. On the other hand, the experience with the evaluation of the Panopticon installation showed that it really sparked discussion about ethical issues such as privacy, surveillance, the internet and advertising, which relate closely to the themes presented in the installation. This strengthens the conviction to continue on the path taken. Both developing more interactive ethics installations and researching how they can be best integrated in a stimulating environment for ethical deliberation.

6 CONCLUSIONS

Interactive ethics installations which engage their target audience through physicality, meaningful interaction and impactful confrontation can stimulate ethical deliberation. The next step is to make them part of a dedicated educational space for practicing ethics in education. Most interesting contribution at this point is that the exposure to the interactive installations as a practical pedagogical method sparks interest and intrigue in the target group, potentially making them more likely to engage with ethical subject matter in their own engineering practice.

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ENHANCING THE TEACHING OF RESEARCH METHODS IN ENGINEERING: CHALLENGES AND SOLUTIONS

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ABSTRACT
Engineering education primarily provides students with the ability to apply scientific and mathematic principles to technical problems, whilst research methodology refers to the process of applying systematic procedures and techniques to resolve research questions. A lack of scientific training, in research methodology, and an inexperience with human data can be detrimental for engineering students when addressing real world challenges. Therefore, the motivation of this paper was to explore innovative teaching methods, to enhance the education of engineering students on a newly developed, postgraduate research methods module. Said module had a view to expanding student understanding and knowledge through planning and conducting qualitative and quantitative research. This paper explores the differences seen between two cohorts of research methods students, delivered within the first term of study across three MSc Engineering courses. Qualitative findings associated with student feedback are presented considering the unique teaching and assessment challenges of delivery to a predominantly international cohort of postgraduate students. Innovative pedagogic approaches were considered based upon student satisfaction feedback, assessment results and the occurrence of academic irregularities. This study aims to share the module design, the approaches used in teaching, a summary of lessons learned from the two cohorts and suggestions for further enhancement of the module.

Keywords: Engineering education, research methods, quantitative method, qualitative method, international students

1 INTRODUCTION
The importance of acquiring knowledge and practical experiences in personal growth and development has been widely recognised. With the right knowledge and skills, individuals have the power to unlock their full potential [3]. Engineering education is an excellent example, as it integrates theoretical principles with practical applications, placing a strong emphasis on developing analytical thinking skills [5]. Furthermore, engineering graduates play a vital role in driving economic growth by creating innovative products and processes, thereby contributing to the success and competitiveness of society as a whole [11].
Due to globalisation and profound changes in the world, engineering education has been faced with new challenges in recent decades. Evidence suggests that engineering graduates often encounter challenges in securing employment due to their deficiencies in problem-solving and decision-making [9]. In addition, there is a growing emphasis and requirement for engineering students to improve their research skills [1, 7]. One of the key components of an engineering education is the teaching of research methods, which enables students to develop critical thinking, problem-solving, and data analysis skills. These skills are essential for engineers to be able to tackle the complex challenges facing society, including climate change, energy security, and sustainable development and the continued development of medical advancements.
Research methodologies refer to a logical and systematic approach to resolve a research problem, using various techniques to collect and analyse data [8]. Previous research has highlighted the lack of scientific training and limited explicit discussion on the issue of research methodology for engineering students [7, 2]. Despite its importance, the teaching of research methods in engineering is faced with several challenges that can limit its effectiveness [10]. Many of engineering students have difficulties

understanding and implementing research methodologies in their field as well as being unfamiliar with the process and procedures associated with collecting and analysing human data. Engineering students are often highly motivated and eager to learn, but they may not be interested in research methods, which can be seen as abstract and unconnected to their practical interests. In addition, students may not have a clear understanding of the purpose of research methods and how they can be applied in real-world engineering problems. It is often hard for engineering students to make a judgment on how to conduct an experimental study, what method to use to collect data and how to interpret the findings. Therefore, it would be beneficial to make the process of research methodology more explicit in engineering education as it improves students' analytical and problem-solving skills and boost their career opportunities.

The current paper examines the creation of a new research methods module, aimed at postgraduate engineering students studying Medical Engineering, Sustainability Engineering: Energy, and Transport Systems. These MSc courses were first offered in September 2021, with each course offering two entry points either September which represents a standard 12-month MSc or January representing a 15-month course and both entry points are offered with a placement option to extend the course length to 24 months. The research methods module is delivered in the first term of study to both cohorts, alongside the capstone project it is the only module that is repeated specifically for each entry point. The module is repeated so that each cohort benefits from undertaking the module in their first term providing them with a comprehensive overview of the research process, an important introduction to aspects such as plagiarism [12] and setting out research skills, that are required in later modules such as the capstone individual industrial or research project for which research methods is a pre-requisite. The paper focuses on the innovative teaching methods used to instruct MSc postgraduate students and the changes made to accommodate the different styles of learning among the individual cultures [13] represented, as 95% of students were international, with English as an additional language (Table 1). A number of changes were made to this module, without changing the overall structure, the learning outcomes or the underpinning assessment methodologies. These module changes are examined through the experiences of the teaching staff, the student satisfaction derived from module feedback, the number of academic irregularities and the academic performance of students. The authors of the paper also discuss the challenges faced during the development process and the strategies used to overcome these challenges.

Table 1. Nationality of Students as % of Cohort (2022)

	Algeria	Egypt	India	Iran	Nepal	Nigeria	Pakistan	Sweden	Sri Lanka	United Kingdom
January	---	---	65.9	4.5	2.3	11.4	2.3	---	9.1	4.5
September	1.9	1.9	51.9	7.4	---	13	5.6	1.9	13	3.7

2 METHODOLOGIES

The present study delves into the student satisfaction survey data collected from 58 postgraduate engineering students, across two separate cohorts (January 2022 and September 2022), who offered their feedback on the research methods module. The survey was completely anonymous meaning participants could not be identified and that the teaching team could not influence the responses from the students in question. All data were analysed and were organised into two distinct categories: quantitative findings and qualitative findings. Incidences of academic irregularity were compared as were the grades for each of the assessment elements and the overall pass-fail rate of the module. The structure of the module consisted of ten weeks of teaching (Table 2). The first five weeks consisted of a one-hour lecture, a one-hour seminar and a two-hour practical computer lab, to prepare the students for the practical statistics assessment in week six of the term. The sessions were all designed with active learning components embedded based on evidence that this approach is advantageous to STEM students from diverse backgrounds, facilitating reduced failure rates and increased grade rates [4]. The first assessment was a practical statistics assessment using IBM SPSS statistics package to answer a research question posed in a scenario with an accompanying data set. All students were asked to complete the assessment at the same time under exam conditions in a computer lab. The assessment was, however, open book, meaning access to notes, internet-based guides and academic texts were allowed but all communication was forbidden. This approach was an attempt to make the assessment a part of the learning experience and not simply a way of identifying what information had been retained by the learner but a more holistic approach that more accurately represents a real-world scenario, whilst ensuring that each students own knowledge and ability is assessed [6].

The following three weeks focused on ethics and qualitative research methodologies using the same lecture, workshop, and practical session format. The second assessment was a presentation with delivery from the students focusing on the use of qualitative research methods to answer a subject specific research question, provided as part of scenario where the students would be pitching the research plan to a board of directors. The final week was a summing up week, ensuring the students understood how the materials covered linked to the rest of their studies and their major project. During the period between delivery of the module to the two cohorts some changes to the module structure were made to try and tackle some of the issues that became apparent. These alterations are discussed in the results section with respect to relevant outcomes.

Table 2. Research Methods module schedule (2023)

Week	Session	Topic
1	Lecture	Introduction
	Seminar	Literature searching, reference management software and plagiarism
2	Lecture	Aims, objectives and hypotheses & defining variables & research methodology
	Seminar	Academic writing
	Lab	Descriptive statistics
3	Lecture	Quantitative data analysis / inferential statistics
	Seminar	Types of data
	Lab	SPSS - T-tests
4	Lecture	ANOVA and non-parametric equivalents
	Seminar	Sampling
	Lab	SPSS - ANOVA
5	Lecture	Correlations
	Seminar	Effect sizes
	Lab	SPSS - Correlations
6	Practical Assessment	SPSS - Stats assessment
7	Lecture	Qualitative research methods and data collection (Interviews)
	Seminar	Reliability, repeatability, reproducibility, and agreement
	Lab	Peer interviews
8	Lecture	Qualitative Research and data analysis (Focus Groups)
	Seminar	Data analysis (Interviews)
	Lab	Focus groups participation [14]
9	Lecture	Ethics
	Seminar	Presentation preparation
10	Presentations	Assessment
11	Lecture	Discussion and conclusion writing
	Seminar	Academic writing

3 RESULTS

3.1 Quantitative findings

The quantitative findings were categorised into four main aspects from the module survey: feedback on module teaching, feedback on assessment and marking, feedback on module organisation/resources and overall satisfaction.

Data for feedback on module teaching for both cohorts showed that 80% of students were satisfied with the teaching quality on the module. Although 73% of students in the first cohort sated that the module was challenging them to achieve their best work, this number increased to nearly 86% for the second cohort. In addition, 78.6 % of students in the second cohort compared to 76.7% in the first cohort stated that the module was intellectually stimulating.

In terms of feedback on assessment and marking more than 96% of students in both cohorts indicated that the criteria used in marking for this module were clear in advance of the assessment. In the first cohort 73% of the students stated that they have received helpful comments on formative or practice tasks they had undertaken within this module. In the second cohort however, this number increased noticeably to 92.9% even though the number of tasks where feedback was supplied to the students was the same. Several reasons for this could be linked to the language used related to session names and the materials provided via the virtual learning environment. Between the running of the two cohorts, language support to ensure clarity of instructions was obtained from the University Languages department. Firstly, the language used in materials (especially assessment based) were simplified and secondly, some support sessions were renamed as coursework drop-in sessions from workshops/seminars.

In terms of feedback on module organisation and resources, similar results were found for both cohorts. 90% of students in both cohorts mentioned that they were happy with module information, module organisation, and ability to contact teaching staff when needed. In addition, more than 90% of the students in both cohorts, stated that the module (including the online resources had provided them with opportunities to engage with other students. Finally, the overall module satisfaction data demonstrated that 90% of students across both cohorts were satisfied with research methods module.

3.2 Academic performance

The data presented in Table 3 shows the academic performance of each cohort based on the spread of the combined grades for both assessment elements and the number of academic irregularities identified per cohort across both assessments. As previously stated, changes were made to the module (that maintained the structure and requirements of the module specification) to try and improve the academic outcomes without negatively impacting on the experience of the students or reducing the challenges presented. The use of language specialist support has already been discussed but other changes included a random allocation of research questions and associated data sets for the practical assessment, using custom assessment tools within the University's online learning environment and a question pool. This coupled with a more in-depth explanation of the concept of exam conditions in the lab sessions leading up to the assessment appeared to reduce the number of academic irregularities associated with the assessment (Table 3).

Table 3. Academic outcome for each cohort based on grade boundary information and number of academic irregularities, presented as a percentage of the total number of students per cohort

	Cohort A (% of students)			Cohort B (% of students)		
	Practical Assessment	Presentation Assessment	Total module grade	Practical Assessment	Presentation Assessment	Total module grade
Fail	49	42	49	31	13	24
Pass	27	33	36	29	44	41
Commendation	22	22	13	22	35	31
Distinction	2	2	2	18	9	4
Academic Irregularity	7	9	16	0	0	0

The other significant change to the module structure was a change to the presentation assessment. Cohort A were asked to produce a seven minute video presentation, using PowerPoint slides and closed captions, for inclusivity. Although there appeared to be genuine enthusiasm for this project, considering the language challenges for a large proportion of the student cohort, a seven-minute monologue appeared to be a step too far and students seemed to struggle to complete the presentation within the time allotted, even though their understanding was evident from the slides produced, which were typically of high quality. Consequently, cohort B were tasked with generating a three-minute presentation with only three slides (a variation on the 3-minute thesis competition concept). Although a much shorter time period, the students were tasked with covering the same content and providing enough depth of information to sell their project idea. This shorter (and very strict) time allowance focused the students and allowed them to practice and hone their presentations, improving their experience, and the academic achievement without reducing the level of assessment. It encouraged their ability to present information concisely and accurately in order to fit within the three-minute presentation window. Furthermore, the use of the shorter presentation time and multiple markers (including rotating second markers) meant that the presentations could be delivered live, offering students another engagement opportunity and an enjoyable event for all to attend. As can be seen in Table 1, not only did the pass rate for the module improve from 51% to 76% but the number of students achieving better grades also increased with overall commendations rising from 13% to 31% and distinctions rising from 2% to 4%. These findings suggest that the students' academic performance and understanding notably improved increased in the second cohort due to changes to the module structure.

3.3 Qualitative findings

The qualitative findings were categorised into two main sections; 1. feedback on the teaching aspects that students found valuable 2. feedback on the teaching aspects that can be improved.

In terms of the feedback on valuable teaching aspects, the results showed that while students in both cohorts found the research methods module challenging, they stated that it was very interesting and helpful.

For instance, a student said;

"*Overall, this module has been very useful for me to learn new things that I did not know before. The teachers have been very helpful and cooperative."*

In addition, students in both cohorts stated that the way module was taught was very clear, interactive and that teachers were always supportive. For instance;

"The teaching was always clear, and explanations were always provided which benefited me as it was easy to quickly get to grips with the different things we were learning."

In terms of further improvements for teaching aspects of the module, most students in both cohorts stated that there was a need to present more examples, provide more video demonstrations and home activities for further learning. For instance, a student mentioned;

"For presentations, it would have been helpful to have a sample or example presentation highlighting the best way to create and present a study".

Another student stated;

"In the quantitative lab assessments, it would have been better to have separate/more questions to practice on. It would have been helpful to understand the different application for each method".

The final change made to the module related to the final week of teaching that occurred after the final assessment had been completed. Instead of using the week to sum up the materials covered and seek to link this to the remainder of the students' studies such as the individual industrial or research (capstone) project in a broad sense. A new session was designed to cover the materials that should be considered in a discussion and conclusion section of a study. This session not only acted as a clear and obvious end to the module but provided students with an opportunity to consider the dissemination of results from any work they were to carry out within their studies and beyond.

4 CONCLUSIONS

This study identified benefits associated with a combined focus on the use of assessment methods that are incorporated within the learning experience rather than simply as tests of knowledge retention. Improvements were identified and made alongside careful consideration of language and assessment instruction for international students with targeted sessions to prepare students for these experiences. This not only improved grade rates but maintained student satisfaction and reduced incidences of academic irregularities. Furthermore, the module provides students with skills and tools that can be used within their work in other modules and highlights how these tools can be used beyond their immediate environment to encourage engagement and satisfaction.

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FINAL DEGREE SHOWS; CULMINATION OR INVITATION?

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ABSTRACT
Final degree shows are often described as a ‘culmination’ – a climax or completion. Is the academy missing an opportunity with this perspective? This paper calls into question the role of final degree shows, exploring the potential for them to stimulate pedagogical and curricular development within a design programme or design school.
There are increasing pressures on universities to engage in socially relevant research and nurture students able to respond to the grand challenges of the modern world. To ensure relevance, the academy must learn with the communities it serves. Whilst much research exists on different forms of collaboration with universities, this position paper responds to a gap in literature regarding the role of public exhibitions and proposes final degree shows as a space for new models of public discourse, providing opportunities for knowledge exchange and stimulating discussion with communities outside of academia in different contexts. Rather than being the end of a conversation, we propose that final degree shows become an invitation to begin.
Using a single case study methodology we describe a snapshot safari activity, held during a final degree show, highlighting key outcomes, and exploring the insights revealed in terms of design teaching and curricula. The paper concludes by proposing models of micro-engagement within the context of a final degree show. We believe these could form the basis of further research in this area giving universities the opportunity to explore specific areas of interest through thematic curation of exhibitions with considered convening of people to discuss them.

Keywords: Final show, degree show, design show, final exhibition, graduate exhibition, design curriculum, design pedagogy, industry-academia collaboration, public discourse

1 INTRODUCTION
This paper proposes that there is untapped value in final degree shows and opens with a literature review exploring the format of contemporary shows and what value they offer the academy. We scan forms of interaction between the public and design academics, and review how micro-collaborations can contribute to design curricula, pedagogy, and knowledge exchange. Through a single case study, we demonstrate how an activity held within a degree show raised unexpected insights from people outside of the academy while responding to the design outcomes of graduates. We suggest these insights could be valuable to academics helping them to tailor curricula and teaching practice to stay relevant to real-world societal and industry needs and challenges. We outline the design and application of the snapshot safari activity and give examples of resulting outcomes. The paper concludes by proposing models which could be used to leverage the final degree show as a space for new forms of discourse.

2 BACKGROUNDS
There are increasing calls for new models of public dialogue, formal and informal spaces for people to connect and collaborate on strategically relevant themes leading to research and innovation for prosperity and public good [1]. As institutions grounded on research and innovation, universities have a responsibility to play a role in developing and engaging within these spaces.
The Knowledge Exchange Framework (KEF) [2] identifies public and community engagement and work, along with local growth and regeneration as key segments of a knowledge exchange (KE) strategy. A systematic review of literature on KE for the National Centre for Academic and Cultural Exchange

(NCACE) [3] shares different types of collaborative engagement but does not feature short-term micro-engagements independent of larger projects.

This review of literature explores two key areas of opportunity:

1. Universities could take advantage of more opportunities to gather insights from and exchange knowledge with those outside of academia to inform their teaching and programmes. We explore the format of short-term collaborations and to what extent they inform curricula and teaching.
2. Universities could leverage additional value from final degree shows. We review literature which describes the value they are thought to bring to the academy.

A systematic literature review on university-industry cooperation [4] revealed research on the value transferred from universities to industry, but nothing on the value industry provides to academia. Siegel [5] covers the impact of medium-term partnerships on the curriculum of summer business residentials, but there is little academic attention on short-term collaborations in relation to curriculum design. Plewa et al [6] describe different methods used to facilitate industry involvement in curriculum design and delivery, measuring the efficacy of these in a variety of contexts but excludes any mention of final degree shows.

A report examining the impact of university-industry cooperation in the context of education [7] covers shared physical spaces, Knowledge Transfer Partnerships, live projects and student placements, explaining how these have been used to co-design and develop curricular with industry. However very short-term micro-collaborations are not covered. Additionally, the cases explored focussed on strengthening the knowledge and skills valued by corporations, rather than those which would be valuable to the social innovator. We suggest that discourse between academics and non-academics during final degree shows through micro-engagement models such as a snapshot safari could be a valuable way of enabling people outside of the university to contribute to and influence socially responsible design curricula.

Rarely mentioned in literature on design pedagogy, the final degree show is an important fixture for many higher education art and design programmes, providing motivation for students presenting their work and promoting the courses on show to external visitors. There is a noteworthy lack of literature about degree shows and what exists covers visual and fine art rather than design shows which rarely appear in pedagogic literature or discourse. Available research covers the process of developing the final show and the value of this to students participating in the process, falling short of any deep discussion on the value of the show to industry, society or the academic institutions themselves.

Final degree shows are considered important to students, they are known to motivate and create opportunities for collaboration [8]. Often happening at the very end of the student experience, the opportunity for students to learn during their final degree show is rarely utilised. Hjelde [9] suggests “foregrounding the critical pedagogical and social dynamics of [the degree show] and considering it as a process, not just the outcome” to deliver on a wider potential and references Bismark (2006) who suggests that we should consider the degree show as a reflexive tool to combine educational, with political socially relevant purposes. Littlewood and Wyatt-Livesley [10] also suggest that degree shows should be more connected to the students’ educational experience. Making work visible in a shared space provides the type of social learning space which Shreeve et al [11] propose as a signature pedagogy of art and design disciplines.

Shows are considered a valuable opportunity for the public to have access to challenging contemporary design and act as a public face for the university, communicating a course identity and philosophy [10] and demonstrating students’ learning and knowledge through material products. In considering other types of value to society there are more questions than answers in the literature. In ‘Making Public: The Fine Art Degree Show’, Leeds Beckett School of Art and Architecture [12] asks whether degree shows affect shifts in the delivery and design of teaching and learning, and questions how programmes are influenced by the local and socio-economic landscape.

The ‘Therapeutic Academy’ described by De Ville and Foster (1994) [9] is distinguished by a “political and social stance where the aim is society betterment”. They suggest the exhibitionesque form of the show hinders its ability to create connection with others. Hjelde [9] agrees “The institution cannot be contemporary in its relationship with society, which is perhaps a problem for a place that educates artists and designers of the future”. Gilmore and Comunian [13] highlight the need for universities to turn toward new models of creative engagement to enable academics, industry, and the public to collaborate in the same spaces. How might we use the degree show to foster discourse and understanding of the exhibition, nurturing the therapeutic part of the university, and providing a way to connect with and better serve society?

Aside from showcasing the teaching of universities and work of students to proud parents, prospective scholars and recruiting employers, degree shows appear to draw little value for the academic institution. No literature was found on the value of shows to higher education institutions in terms of pedagogy, or on their use as an environment for encouraging discourse with public communities aside from 'industry partners' – this paper offers a response to this opportunity.

3 POSITIONS

We propose that leveraging additional value from graduation exhibitions through new models of public discourse as a part of design pedagogy would provide an opportunity for further research which this paper begins to address.

4 METHODOLOGIES

Unexpected outcomes triggered this research study, when valuable points relevant to design pedagogy were being raised during discussions as part of a snapshot safari activity at a final degree show. We used auto-ethnographic insights from a place of 'insider research' [14] to explore these, mindful that within this emerging intuitive inquiry [15] [16] our positions and perspectives influence our interpretation of research data. This qualitative, participatory case study gave us flexibility to reflect on the experience of the snapshot safari activity without a previously constructed hypotheses or a predefined set of outcomes [17]. We consider this research as a potential first step in a longer period of inductive theory building [18] which given a more substantial body of data could reach conclusions or generate theory.

5 RESEARCH ENVIRONMENT

In June 2022, a UK university design school hosted a conference to encourage discourse on the ways design can be used to identify, respond to or address social issues. Attendees included:

- 9 academics from a research network focussing on multidisciplinary innovation for social change. These academics held teaching and research roles in a wide range of disciplines, other than art and design, from different pan-European universities.
- 19 scholars from the host university who all actively contributed during the event. They included Masters' students, PhD candidates, teaching and research staff from different design disciplines, (the authors are part of this group).
- 11 practitioners from (largely local) organisations including charities, social enterprises, small businesses, and independent consultants working on projects to further social justice. Largely non-designers, they all had a relationship with the design school as alumni or collaborators. Some spoke in the conference.

6 CASE STUDY

A snapshot safari activity was designed as part of the conference to create a safe, inclusive, and effective space for discourse. It included periods of individual work, followed by group collaboration and discussion, accommodating a variety of visual, aural, read/write, and kinaesthetic (VARK) learning styles [19]. Visual learning through photographs and posters as primary tools for communication finding common ground between people of different native languages and disciplinary vocabularies, auditory learning through the conversations between different people, read/write-learning via text which accompanied the degree show exhibits and kinaesthetic learning through the active experience of creating paper posters.

The snapshot safari was made up of three consecutive activities:

- Activity 1 Individual response to a photography brief
- Activity 2 Small group conversation and poster-making
- Activity 3 Whole group discussion on the poster exhibition

In activity 1 people explored the final degree show exhibitions (3D Design, Architecture, Industrial Design, Fashion Design, Fashion Communication, Graphic Design and Interior Design), with a brief inviting them each to take 6 photographs illustrating 'design for social innovation' (the conference theme). Questions invited people to think about what design for social innovation meant to them and how it might relate to or influence their own practice.

During activity 2 people formed 3 groups, each joined by a design academic who facilitated conversation on their photos exploring their interpretations of 'design for social innovation'. Groups created posters using their photos and annotations to respond to the question "How should we live?". Finally for activity 3 posters were displayed and each group presented theirs. The whole group discussed the posters exploring the various ways they had responded to the brief.

7 RESEARCH DATA

Data on this case study was collected through:

1. Auto-ethnographic observations (as designers of/participants in the activity)
2. A systematic literature review focussing largely on literature since 2018.
3. Audio transcription of group discussion during the poster exhibition
4. Photographs of the safari process and exhibition posters created [20]

Following an Intuitive Inquiry methodology [16] observations (1) were used to determine the positioning for this study and frame the literature review (2). Then data from the transcription (3) and posters (4) were analysed, the preliminary interpretive position tested and modified based on that data.

8 LEARNING

As subsequent posters were discussed during activity 3 of the snapshot safari, recurring themes around the role of design in social innovation emerged, and the conversation began to move to aspects of design education. People asked questions about the student experience and shared thoughts on how the students, teaching and curricula might have influenced outcomes.

Qualitative analysis of this group discussion data revealed feedback of two main types.

- Experiential insights from all participants having participated in the activity.
- Pedagogic reflections from academics and scholars on how different curricula and teaching styles impact the student experience and outcomes.

Participants described experiencing a sense of optimism and hope through pieces they viewed, others felt inspired by interesting and clever exhibits. Many shared how they were drawn to exhibits which showed humour, relevancy to their own practice, or represented quality production. Some people found the exhibition overwhelming, with so many exhibits from different disciplines, but felt the safari brief and timeframe, helped them focus and was useful in framing or filtering their experience. Overall people enjoyed the activity and the opportunity to discuss it together.

Participants commented on the fact that the most impactful exhibits tended to be person-centred, relating very clearly to an individual that the designer knew. This led to a discussion on the importance of design in raising awareness within society of the need to shift away from the paradigm of competition and capitalism. One participant suggested the positioning of the design school within the academy could be important, the social impact of design work perhaps being easier to tease out where the design and social sciences faculties co-exist, than in an academy where perhaps design and engineering belong together.

Further discussion focussed on the fact that while some objects were very well designed and produced, perhaps there was no real need for them in the world. Participants felt students should be given the opportunity to take part in discourse around their work to understand that it could be perceived as unnecessary and reflect on this tension of design. People felt it would have been interesting and valuable to speak to the student designers during the safari to understand why they created their designs and give them the opportunity to share what could not be exhibited. Some academics pondered whether we could nurture more rounded and inclusive designers by amending assessment schedules to allow for discussion on design ethics paired with reflection on final exhibits. People commented on the obvious maturity in the work of students who had spent part of their course working in industry, giving them valuable experience in how their work interacts in the real world and its impact aside from simply looking great.

9 LIMITATIONS

This preliminary study took place with a small number of participants, many who knew each other or shared an interest in social innovation/responsible design. Outcomes are likely to be different with a group who have not previously met or lack a shared focus. A limitation of this study is the restricted amount of data gathered. Had we realised how deep and rich the discussion would be and foreseen the potential for it to be research material, we would have planned to collect data more purposefully. In the timeframe of this study we were unable to confirm whether this activity triggered any curriculum or teaching changes, or simply started a reflective process. While these factors limit this study, they serve as an opportunity to run research in other contexts and around other themes, with greater rigor, planning and reflection.

10 REVISED POSITION AND PROPOSITION

That the academic participants of this safari found value in the conversations which took place during the snapshot safari indicates that there is un-tapped value which could be leveraged in creating more space for public conversation around design exhibitions. It is possible that a purposeful brief can help an audience engage with an exhibition curated by design discipline rather than theme. It is clear from this case study that finding an opportunity for groups of teaching staff to discuss final show exhibits can reveal useful pedagogic and curricula insights.

The positioning of exhibitions at the end of the teaching year limits opportunities for students to engage in reflective conversations. We propose that design schools could create space to share work during the design process, gathering perspectives from communities outside of academia. Students could engage with this discourse as a part of their learning experience before finalising their work. Models of micro-engagement (such as that covered in this case study), could provide a valuable opportunity for teaching academics to draw critically and purposefully from public discourse. This would provide an opportunity to loop back to inform the curricula, briefs and challenges students engage with in following years.

This study does not cover digital gatherings or exhibitions outside of the academy, neither do we examine the value of final shows to communities outside of the academy, therefore these are areas open to further research. As we consider future opportunities to gather around design shows, we will need to think deeply about who the academy might want to include and how they might benefit from the discussion. What shared contexts, thematics or challenges might help to bring diverse groups together? How might we use reflective shared spaces to discuss work in areas of design without physical materials to exhibit? What might the academy learn from other forms of contemporary design-focussed gatherings? The authors plan to carry out follow-on research covering some of these areas during the degree shows of summer 2023.

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DESIGNING CROSS-DISCIPLINARY PROGRAMMES TO DEVELOP THE ENTREPRENEURIAL SKILLS OF ENGINEERING DESIGN & BUSINESS STUDENTS

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ABSTRACT
It is desirable that current and future employees have a range of skills, be adaptable to challenges, collaborate with internal and external stakeholders, and are creative in finding new solutions to problems. To achieve this, developing the entrepreneurial skills of students is beneficial for future employers and the students themselves. This can be achieved by educating students on the factors which influence commercial success including technical feasibility, market desirability and commercial viability. An observation was made that engineering design students are typically highly skilled in developing creative & technically feasible solutions with the user in mind, and business students are highly skilled in developing commercially viable proposals. This paper details what happens when a cross-disciplinary educational intervention is conducted between engineering design and business students for mutual skills development. An 8-week pilot programme was designed at the University of Strathclyde where six teams of business students were paired with a student engineering design mentor to provide advice and guidance on the technical feasibility and viability of the commercial propositions being developed by the business students. The outcomes of the programme were in the technical and softs skills development for the engineering design students, the development of stronger commercial proposals supported by tangible assets for business students, and a greater appreciation of client/consultant negotiation and communication for both disciples of students. Recommendations are shared for those who are considering the development of similar programmes in the future.

Keywords: Entrepreneurship programme, engineering design students, business students, project-based learning, entrepreneurial skills development, tutorship

1 INTRODUCTION & LITERATURE REVIEW

Universities offer their students a safe environment to learn and practice entrepreneurial skills before entering real-world trade. Students may choose to attend university for personal reasons perhaps including knowledge building and skills development on particular topics which they choose to study. Within an educational environment there can be limited opportunities to design authentic experiences within the curriculum without specific interventions such as a placement within a company. However, specific lessons can be designed into the curriculum giving students an experience of and the knowledge to overcome challenges they may face after graduation. For students studying entrepreneurship related subjects or on a path towards it they need to build the skills to support their personal and professional development.

The question of 'how relevant entrepreneurship knowledge and experiences is to product designers' has been well addressed in literature [1]. Proposals have been made of innovative product design approaches to enhance innovation and entrepreneurship in design and engineering students [2], and others speak of the importance of combing market, design and innovation education together [3].

From a pedagogical perspective, bringing together design and business students for inter-disciplinary projects has learning benefits and develops transferable skills. Business students gain a better appreciation of user-centred design and have creativity skills enhanced. Design students gain a great appreciation of commercial elements such as finances and marketing [4]. When combined, all students gain a more rounded appreciation of design and commercialisation, and how the two concepts are required for successful product development and launch.

At the University of Strathclyde an observation was made that further supports the work of Baelus [4]. Engineering design students are typically highly skilled in developing creative & technically feasible solutions with the user in mind, and business students are highly skilled in developing commercially viable proposals which consider financial and marketing aspects. This observation has led to a motivation to develop an educational intervention bringing both disciplines of students together.

The need for this work is supported by government initiatives in the UK including 'Developing the Young Workforce'. As our world evolves through Industry 4.0, there is a growing trend for the educational sector to develop graduates with transferable entrepreneurial skills going well beyond their subject of expertise [5] in order to better prepare students for the world of work [1]. This growing trend is being well documented in literature, with many academics acknowledging that 'a conventional academic degree alone is no longer sufficient' [5]. There is a growing desire for multi-skilled, adaptable, collaborative & entrepreneurially minded students as it is well understood that an entrepreneurial mind is crucial for future commercial exploitation of new opportunities [3]**.**

State-of-the-art research in this area is currently investigating how to develop transferable skills, and acknowledge that in order to cultivate talent, the integration of entrepreneurship education and design education is key [3]. Progress is being made to address this issue through various work such as Spruce [5] discussing an initiative at Liverpool John Moores University called World or Work (WoW) and Mallins who cites a project looking to better connect students with industrial experience [6]. Sandy [7] also looks at a 2-month study providing students with a structured process for developing their ideas [7]. Two studies of particular interest in our work are by Baelus [4] and Tran [8], both of which look at the development of programmes that bring together business and engineering/design students and provide a strong foundation on which our work is based.

This paper describes the design and evaluation of a programme to develop entrepreneurial skills in engineering design and business students through a cross-disciplinary Project Based Learning (PBL) educational intervention. The methodology for the design, delivery and evaluation of this programme is detailed in section 2. Results and discussion are presented in section 3 with a reflection on the limitations of the programme and recommendations for future development and advice for others who may be interested in implementing such programmes within their institutions. The conclusions in section 4 present a summary of the research and the findings.

2 METHODOLOGIES

In this section, the methodology for the design, delivery and evaluation of a cross-disciplinary to develop entrepreneurial skills in engineering design and business students is presented.

2.1 Design of the programme

To bring engineering design and business school students together an 8-week pilot programme was developed. The programme asked students to put into practice the skills and knowledge developed in order to create a convincing and consistent business proposition. Students were expected to identify a suitable business idea, use market research and prototyping for validation, and present two equally comparable, but different, strategies to grow their business. The programme formed part of the business student's Masters level project and was a self-directed and supervised class for the business students to research and validate their ideas. Incorporating the engineering design students was through a paid internship opportunity for those in their 3rd, 4th or 5th year of a Masters or Bachelor's degree in Design Engineering, or 1 year Post Graduate Design Engineering programme.

2.2 Delivery of the programme

The pilot programme ran throughout Jun & July 2021. Business students were asked to form teams based on their ideas and the skills they required. To better understand these teams, students were asked to complete a group formation form, detailing the team members, the skills they currently possess & gaps they may have, their commercial idea, and what they hope to achieve from the programme. To find suitable design engineering mentors a job advertisement was created by class coordinators and advertised to the engineering design students. At this stage, the engineering design students were not given information on the business student group formation forms. Interested engineering design students, were only asked to submit a CV detailing skills and expertise for consideration by the class coordinators. Class coordinators of the programme then matched the skills stated on engineering design CVs to skill gaps stated on Business students group formation forms. This project was financially backed by the Hunter Centre for Entrepreneurship at the University of Strathclyde and engineering design mentors were paid an hourly rate to a maximum budget of 30 hours of support per group. Each business student group was supported by one engineering design mentor. Two engineering design mentors supported two projects each and two engineering design mentors supported one project each.

2.3 Evaluation of the programme

Upon conclusion of the pilot programme, feedback was collected from the participants to evaluate the experience. Engineering design mentors were consulted during an open forum focus group session. Two of the four mentors took part in this session. Further reflective interviews were then conducted via email with the engineering design mentors in January 2023. Three of the four mentors took part in these interviews.

Business students were not interviewed upon conclusion of the programme; however informal discussion was held following their graduation from the course. They were then formally interviewed in in January 2023. Three students took part in the formal interviews representing three of the six teams.

Questions asked during the follow up interview were:

1. How did you find the experience of working with students from another discipline in general?
2. Were there any challenges?
3. Were there any highlights?
4. Did the experience of working with the students from another discipline enable you to develop your soft skills? If so, which skills were developed?
5. Did the experience of working with the students from another discipline enable you to develop your technical skills? If so, which skills were developed?
6. Reflecting on the experience of working with the students from another discipline, is there anything you would have done differently? Is there anything you would suggest is done differently if this programme were organised again in the future?
7. If you could rate the following aspects of the experience on a scale of 1-10 (10 being high), how would you rate them?
    a. Helpfulness in developing my soft skills,
    b. Helpfulness in developing my technical skills.

An additional question was asked of the business students being:

    c. Helpfulness in pursuing the idea further out with my studies.

3 RESULTS & DISCUSSION

3.1 Reflections of the Engineering design students’

The open forum discussion with the engineering design students suggested the programme was a success and different than that which they had experienced during their studies so far, describing the experience as “invaluable”. An interesting detail was that in some cases, engineering design student mentors went above and beyond the allocated budget of 30 hours as they recognised the benefits of the skills development to their own personal development as a designer.

Covid-19 restrictions on face-to-face meetings were in place at the time of the programme and this was reported as a challenge for communication. It is unclear if this influenced the lack of project clarity communicated from the business students at the start of the project, or if this would be present under normal circumstances. Overall, students suggested their technical and soft skills had been greatly enhanced by the programme. The interviews which took place in January 2023, provided further insights.

Question 1. Challenges highlighted mainly focussed on Covid-19 restrictions making communication more challenging. Time management was also highlighted as a key challenge. As the engineering design students also were not with the business student daily, this resulted in project direction and project clarity challenges. Engineering design students also reported that the business students lack of understanding of the design process meant time had to be spent educating the business students. The short time frame for the project was also another challenge.

A key highlight for the engineering design students was seeing work they created being used well after the programme had finished in the start-up’s that were created from the programme i.e., logo and branding. The students also had a much better understanding of what it would be like being a freelance designer & could see how their soft skills were developed. In addition, the programme also provided network expansion opportunities, and it was noted that some of the students still stay in touch with each other.

Question 2. The key soft skills that were highlighted as being developed were time management, communication, adaptability, ability to manage criticism, and confidence.

Question 3. The main technical skills development was in those that were new to the student and/or had not been taught on their respective courses i.e., wire framing and UI/UX design skills.

Question 4. On reflection, the students themselves said they should have tried to maintain more regular communication/meetings throughout the project duration with their groups, and they should have tried to establish better clarity from the project onset on expected project deliverables and outcomes.

Suggestions for improving the project included providing engineering design students with a broader range of projects to work on and a more formal ‘royalty’ agreement between engineering design and business students. In addition, running the programme over a longer timeframe and providing more paid hours to support the business student if requested.

Question 5. Asked for a quantitative answer with the average response to the ‘Helpfulness in soft skills development’ being 7.7/10 (individual responses were 8, 8, 7) and in response to ‘Helpfulness in technical skills development’ being 6.7/10 (individual responses were 7, 7, 6). Responses were very similar and positive for both questions.

3.2 Reflections of the Business Students’

It was reported through communication with the students upon their graduation, that of the six business student teams supported, four went on to engage with external support services for developing their ideas further after they graduated. From this, two registered businesses, and two continued to explore the ideas at idea stage out with their university studies. Three business students responded to our interview request in January 2023, their responses are now discussed.

Question 1. The main challenges focussed on educating the engineering design student on the market in which the business students wished for them to work. This is not unexpected, as the engineering design student is completely new to the project area, in comparison to the business student who already knew the area well from having developed the proposal. Covid 19 was also noted as being a challenge due to the implications this placed on face-to-face meetings and communication, however this is not a unique challenge to this project, and similarly was noted as a challenge by the design engineering students. The key highlights for the business students that was noted was in the high-quality outputs & attitude & self-motivation of the engineering design students (‘diligent and charismatic’). This suggests effective selection of the engineering design students with a skill set that added value to the business students.

Question 2. Two of the students answered there that were no soft skills developed, however one student responded that they felt their communication and people management skills were enhanced.

Question 3. No technical skills development was noted. However, a comment was made by one student that this was seen in their view as positive, as it allowed them to focus on commercial and business aspects of their business, which was their area of interest, rather than trying to learn new technical skills.

Question 4. There was limited reflection from the business students on what they could have done differently, however they did note more face-to-face communication would have enhanced the experience. They also did suggest that the programme could be improved by better alignment/pairing of engineering design students in terms of their interest in the project area, and perhaps consider providing the business students with a team of engineering design students rather than just an individual. Again, this feedback is similar to that of the design engineering students, who suggested it would be good to work on a broad range of projects.

Question 5. It was stated by all business students that the design student was not a factor in pursing the project beyond the programme, however a good relationship was still maintained between both students.

Question 6. Asked for a quantitative answer with the average response to the ‘Helpfulness in developing soft skills’ being 4.7/10 (individual responses were 2, 4, 8), in response to ‘Helpfulness in developing technical skills’ being 1/10 (individual responses were 1, 1, N/A), and in response to ‘Helpfulness in pursing the idea further’ being 2/10 (individual responses were 2, 2, N/A). Responses were very similar and negative for these questions.

Comparing the experiences of both students there are clear differences. For the engineering design mentors the experience was positive and these students were able to reflect on the positive skills development they experienced. On the other hand, the business students did not have a positive experience related to their skills development. It is unclear why this is the case but perhaps there is a difference in the reflection skills of the students or the emphasis they put on the importance of building these skills. This is something we wish to investigate in the future.

3.3 Recommendations for future development

There are lessons learned in the approach to this pilot project which now provide recommendations for future work.

1. In this pilot, the commercial ideas the business student groups would be working on were not disclosed until the engineering design student was allocated to the group. A specific job advert for each business student group, would perhaps allow better matching of engineering design skills with skill gaps stated by the business student groups and allow for better alignment of engineering design student to project areas of interest.
2. Engineering design students were not interviewed for the internship, and were selected only based on skills stated on their CV. It is recommended that an interview process or 'speed dating' activity for engineering design student recruitment would provide better skills/project interest matching and also ensure engineering design students selected continue to be motivated by the skills development opportunity.
3. No design development process education had been given to the business students prior to this project.
4. Groups were not consulted or asked how much time they thought they would require. All groups were provided equal hours (30 hours total), however during the project some did not use all the hours available, and some asked for additional hours. In terms of engineering design students, some also went above and beyond allocated hours (which was therefore unpaid).
5. This pilot was run during Covid-19 pandemic restrictions, therefore most interaction between the engineering design and business students occurred online.

To overcome these limitations recommendations have been created.

To overcome limitation 1. it is recommended that specific job adverts should be created for each business student group detailing the project proposed & providing further details on the market they will be targeting.

To overcome limitation 2. it is recommended that engineering design students should be invited for interviews or a 'speed dating' event with the business students.

To overcome limitation 3. it is recommended that design development overview workshop with business student's prior the programme commencing to ensure a good appreciation of the design development process and provide a more realistic appreciation of what can be achieved in the given timeframe when working with the engineering design students.

To overcome limitation 4. it is recommended that ask the business students to propose how much support & time they would need from an engineering design student.

To overcome limitation 5. it is recommended that encourage face to face meetings and communication between engineering design students and business students. It is recommended that students are encouraged to meet at least once per week.

In addition, two further recommendations were created which do not relate to a specific limitation identified these are: to provide design engineering students with at least two projects to work on in order to allow them to develop skills in different areas or consider running the programme with engineering design students working as a collective group managing and working on all business student projects, and to situate the design engineering students as full-time group members, with remuneration in terms of class credit rather than payment. Although, the skills development opportunity is seen as being most beneficial to the engineering design students, and less so for the business students, it was still seen as a positive experience for the business students in providing them with valuable, high quality, tangible assets that allowed them to develop their ideas further. The business students were also able to more fully focus on developing stronger commercial propositions, as their time was not wasted trying to learn new technical skills. On reflection, the programme was primarily beneficial in developing the soft and technical skills of design engineering students and providing business students with an appreciation of the design process and in allowing them to focus on developing strong commercial propositions supported with tangible business assets to develop their businesses further.

4 CONCLUSIONS

An entrepreneurial mind-set is crucial for industry, where there is a growing desire for multi-skilled, adaptable, collaborative & entrepreneurially minded students [3]**.** In the presence of Industry 4.0, the educational sector must be developing graduates with transferable skills that go beyond their subject of expertise, as the conventional academic degree is no longer enough [5].

This paper looked to address this growing need for more entrepreneurially minded students and to explore the educational benefits to the students of bringing together cross-disciplines to work on solving real world problems. To achieve this groups of business students were paired with an engineering design student to function as a mentor in product development. Upon completion of the course both sets of students were interviewed to evaluate the success of the programme. The outcomes of this evaluation are a set of recommendations for future development of the programme supporting student satisfaction and coordination of the educational experience.

It was identified that mentors and business student groups could be better aligned based on personal interest or through interviews. Business students should be given education on design process for an appreciation of the design process. The contribution of the mentor to the product development was not equal for all who contributed which could be formalised. And it is recommended that more face-to-face meetings are encouraged & facilitated. Also, it was identified that the design students could contribute to more groups at one time, and they may be situated within the team in exchange for class credits rather than as a paid mentor.

Further investigation is required to determine why the business students did not share the same reflection of the value of the experience as the design engineering students received from the process and if the programme design can be changed to better support the commercial propositions of the business students.

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RE-THINKING STUDENT DESIGN PROJECTS FOR SUSTAINABLE CONSUMPTION

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ABSTRACT
Sustainability has become a core constituent of most undergraduate Product Design courses. However, many students continue to struggle to put theory into practice when undertaking design projects, often due to their complex nature and conflicting priorities. Considerations regarding sustainability may be limited to the recyclability and reusability of parts and materials, along with attempts to reduce raw material and energy consumption. While their intentions may be admirable, they do little to address the problems associated with human behaviour that are largely responsible for creating most of the global pollution and waste.
In recent years, level 5 students on the Product Design course at Bournemouth University have undertaken live projects in conjunction with the BroomeJenkins Product Design Consultancy. The design brief set by the industrial partner has required students to reappraise the nature of consumption, placing emphasis on alternative modes of acquisition within circular economies. The aim being to challenge students to identify opportunities to innovate beyond the traditional boundaries associated with design and manufacturing. One obstacle this presents is: how to tackle conventional modes of thinking that support economic and societal barriers to change? Something which requires students to reflect critically on their own paradigms and preconceptions.
This paper discusses some of the difficulties encountered when attempting to encourage undergraduate design students to adopt more effective sustainable design practices. It discusses the experiences of those involved in the project and appraises its effectiveness as a means of embedding sustainability in student work more successfully.

Keywords: Circular economy, sustainability, student design projects

1 INTRODUCTION
A study undertaken in 2009 [1] investigated the product-related decisions that undergraduate design and engineering students made when purchasing and designing new products. The purpose of that study was to better understand what was important to those students, both as consumers and as designers and creators. The students surveyed had already attended lectures in which the impact of manufacturing (sustainable or otherwise) on the environment had been discussed. As a result, they had been provided with the relevant information and insight to be able to recognise the significance of sustainable themes in relation to design and consumption. However, the study found that most students were never-the-less influenced predominantly by traditional drivers such as cost/profitability, quality, and aesthetics. At the same time, it found that the same students put the least emphasis on sustainable issues such as environmental impact, fair trade, or ethical policy, despite efforts having been made to raise their awareness of these issues in relation to their subject disciplines.
Since that study, environmental factors relating to industry and manufacturing have become more prevalent and the need for change seen as even more urgent [2]. Attitudes and insights have advanced, with more and more emphasis placed on shifting away from low-impact methods like downcycling, and more towards holistic approaches like cradle to cradle and the circular economy [3]. However, it is our experience that there has been relatively little change in the way undergraduate design and engineering students go about developing new product designs, and that outdated tendencies prevail. Students at level 5 and 6 seem to struggle to apply fundamental concepts such as life-cycle analysis and the three

pillars of sustainability within the context of a design project, where parameters can be less tangible or defined.
In 2020, a level 5 (second year) project brief was set to a cohort of Product Design students, requiring an expansion of traditional design thinking to tackle circularity as a design priority and to explore how design can moderate unsustainable user behaviour. This was a live project, developed in conjunction with an industrial partner, to emphasise that this matter is of concern to those with a commercial perspective as well as academia. The aim of the project was to inspire the students to think more laterally about the nature of human behaviour and the role consumption typically plays in fulfilling the wants and needs of society.

2 THE DESIGN PROJECT

2.1 Project Rationale

From the industrial partner's perspective, the inspiration that led to this project was a critical change of direction after many years of experience of working in the product design industry where commercial viability, efficiency and success were imperative. High volume/low-cost manufacture, a cycle of excess and waste, as well as a perception of low value for the finished goods are all prevalent. To challenge this issue, emphasis was placed on longevity and product lifecycle and how designing a product that can be repaired or re-used significantly alters the established approach to designing all kinds of consumer goods.
The primary aim was to provide a range of topics as a team-based design project. In recent times, the established approach to product design has moved beyond form and function to become more user centric. However, a design outcome may still result in a linear approach and use of materials and resources, i.e., what the Dame Ellen MacArthur Foundation describes as 'take, make, waste' [4]. This project was intended to introduce a more expansive way to think about solving design problems, along with the ideas of circularity, the reduction of waste and the total product life cycle.
Whilst technology can play a role in solving current and future problems [5], this project allowed more space to consider user behaviour. So rather than only taking a technology led approach, addressing the task encouraged the teams to consider bad habits and wasteful behaviours enabled by the way some existing products have been designed, what value the user places on the product and how they are used. Although as a cohort most undergraduate students are accepting of the cause of climate change and the need to act more sustainably, this project put the need to innovate more expansively in relation to how and what they design, how a product is made, used and what happens at the end of its life.

2.2 Project Delivery

The students worked on this project in teams so that they could benefit from the distribution of labour during what would be a potentially complex project in a relatively short, 4-week period. They were split into teams of five or six, with guidance given regarding team dynamics, time and project management, skills, roles, and responsibilities.
In developing the project, it was considered important to provide the students with as much context and source material as possible, to help inspire and encourage their enquiry. Students were also introduced to publications and exemplars [3], [4] to broaden their frame of reference, including challenging orthodoxies of say ownership, or whether recycling is sufficient as a measure to mitigate its impact. Additional time was spent exploring the notion that in the developed world society currently thrives on employment and consumption, and that every industrial process has an impact, even recycling. To help frame the responsibilities faced by designers, the uncomfortable truth that designers might be part of the problem is addressed and, how solutions might be found through an informed view and creative thinking is considered [6].
The project briefing emphasised that the most successful projects should demonstrate a more expansive approach beyond the established physical attributes of product design such as form and function, materials, and processes. Evidence of consideration of how human behaviour will determine whether society will become more sustainable and how future design proposals will not simply be a technology led developments being required. However, the scope of the project was set with sufficient freedom to suit the different interests, knowledge, and skills of the respective teams.
As sustainability is a very pressing and complex issue, there are always new opinions and strategies emerging, such as those proposed in the book 'Expand: Stretching the Future by Design' [7]. One of the

greatest challenges in becoming more sustainable as an industrial society is reconciling the commercial-economic challenges with the environmental-sustainable challenges. Despite the manufacturing, agriculture, transport, and construction sectors moving towards a more sustainable model, and recognising the environmental and economic benefits, there are competing forces to reconcile. It is important therefore that the contextual presentation made at the briefing stage is up to date with the latest thinking.

As the project progressed, each team met with their tutor to discuss and refine their proposed projects. During this time, key priorities were discussed for the teams' attention, typically around project scope, emphasis planning and team organization. To create a real-world experience, the industrial partner acted to some degree as a client would. The teams met with the client to present their preliminary concepts. This was a key milestone in the project as it offered a rare opportunity for students to experience a designer/client interaction first-hand. Teams that demonstrated particularly progressive ideas but that lacked out-right feasibility were not necessarily discouraged from pursuing their ideas in greater depth. The teams would go on to present their final concepts to their tutor, client, and peers, and at that point the robustness of their ideas would be scrutinised in more detail. This required the teams to work towards a clearly defined deliverable that would bring all their skills into play.

2.3 Project Outcomes

Since the project was first run in 2020, a tendency has been observed for some teams to initially identify rather conservative problems to address, including focusing on the design of packaging and cleaning products. This is indicative of the challenges students face in dealing with the complex nature of product design and comprehending that there is more to addressing sustainability than changing materials or facilitating recycling. In response, the project has been adjusted year on year to encourage greater aspiration while providing focus with issues such as problem scoping and ideation. A relatively diverse array of projects have subsequently been forthcoming, from re-thinking the humble kettle to more ambitious challenges such as packaging-free retail solutions, the reduction of waste created at festivals and reducing technological obsolescence associated with outmoded home entertainment equipment.

All teams involved have appreciated the experience of working in a team and with the shift of emphasis that comes with it, while the industrial input provided welcome impetus and focus. The success of the projects differ in every aspect and were invariably influenced by team dynamics and individual skill sets. In some cases, a team would be particularly well informed and engaged and present extremely thought-provoking ideas that were well executed. Invariably those teams lacking a critical mass of engaged team members tended to struggle the most to reach their full potential.

2.4 Follow-up Survey

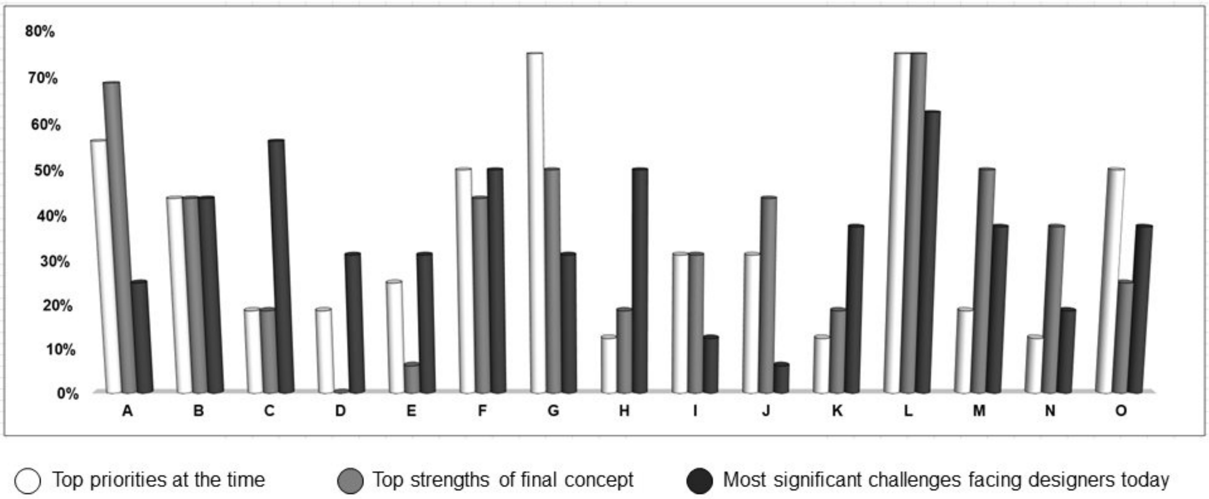
In a follow-up survey, seventeen former students who had previously undertaken the project, completed a two-part questionnaire in which they were first asked to select their top five design issues from a list of fifteen. In practice, it is likely that the teams attempted to address more than just five design issues from the available list, but this restriction helped to provide a consistent breadth for comparison. Issues were selected against three different criteria, to indicate the students': Top priorities for the project at the time; The top strengths of their final concept; The most significant challenges designers face today. In the second part of the survey, the same students were asked to indicate how they were influenced by the project's philosophy via a series of questions (using a 5-point Likert, where 1 = Not at all, 2 = A little, 3 = Moderately, 4 = A lot and 5 = Totally).

3 DISCUSSIONS

3.1 Student Perspectives

The results of the follow-up survey provided a means of comparing students' perceptions at a glance. Overall, the results reflected tendencies that had been expected while also providing some unforeseen insights. In part 1 (Figure 1), many students reported prioritising eradication of disposable products (F: 50%), extending products' service life (G: 75%), Reducing waste going to landfill (L: 75%) and using sustainable/recyclable materials (O: 50%), all of which are typically associated with sustainable design and so were mostly anticipated. However, 56% students also reported prioritising aesthetics (A), even though it was not emphasised as a critical dimension of the project. Optimised ergonomics/interaction (I: 31%), providing consumers more choice (J: 44%), USP (M: 50%) and user convenience (N: 38%)

were judged by a significant number of students as successfully achieved, suggesting they considered themselves competent in these areas that feature regularly in the conventional design process.



KEY

A. Attractive product aesthetics.
B. Challenging traditional modes of consumption.
C. Competitiveness in the market.
D. Design for least cost.
E. Eliminating plastic waste.
F. Eradication of disposable products.
G. Extending products' service life.
H. Influencing human behaviour.
I. Optimised ergonomics and user interaction.
J. Providing consumers more choice.
K. Reducing energy and resource consumption.
L. Reducing waste going to landfill.
M. USP (Unique Selling Point).
N. User convenience.
O. Using sustainable/recyclable materials.

Figure 1. Follow-up survey results part 1

Conversely, it would appear that most students considered themselves less successful in achieving competitiveness in the market (C: 19%), design for least cost (D: 0%), elimination of plastic waste (E: 6%), influencing human behaviour (H: 19%), reducing energy/resource consumption (K: 19%) and using sustainable/recyclable materials (O: 25%). All areas worthy of attention in the context of the overall project's aims. The low number of students' perceiving success in eliminating plastic waste compares poorly to that of reducing waste going to landfill (L: 75%) which was the most frequently selected top strength overall. While these are clearly linked in certain contexts, this discrepancy probably reflects the fact that not all the projects were focused specifically on plastic products.

One of the most frequently selected challenges facing designers today was challenging traditional modes of consumption (B: 44%) which was selected by an equal number of students as a high project priority, top concept strength, and most significant challenge for designers today. On the other hand, influencing human behaviour (H) was considered a project priority and concept strength by far fewer students (13% and 19% respectively) while it was seen as a most significant challenge by 50%. Competitiveness in the market followed a similar trend (C: 19%; 19% and 56% respectively). Speaking with students at the time and subsequently, it is evident that some of them struggle to resolve the issue that human behaviour is largely influenced by cost and that (in their view) sustainable design is likely to raise acquisition costs rather than lower them, hence reducing market appeal. Eradication of disposable products (F: 50%) and reducing waste going to landfill (L: 63%) were also frequently selected as the most significant challenges for designers and represent some of the most tangible consequences of poor design and consumption choices prevalent today. Whilst most students considered their concepts addressed these issues successfully, it is clear that they envisage this problem will persist.

The results of part 2 of the survey (Figure 2) indicated that the majority of students moderately agreed or more with all five statements concerning design philosophy, indicating that most found the project inspiring and influential. 88% of them acknowledged that the project had encouraged them to adopt a different approach to design, and 100% of students agreed that they aspire to apply a similar environmental philosophy to all their future work to at least some extent. The lowest level of agreement was with the statement concerning whether the students' final year projects had been influenced by the project. Although 59% indicates that there is scope to encourage more students to tackle these issues at a higher level, this is not altogether surprising when the complexities and conflicting requirements that students find themselves presented with for the first time by a final year design project are taken into consideration.

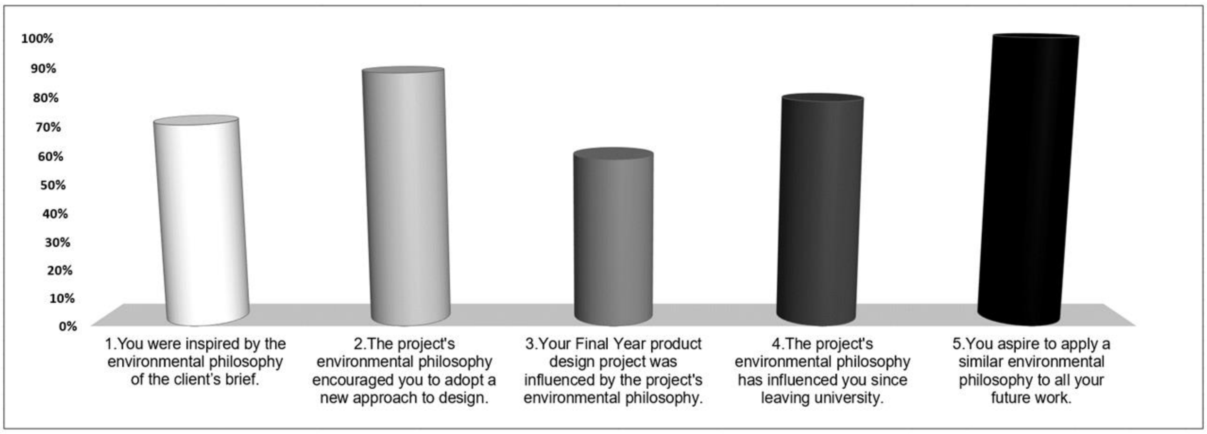


Figure 2. Follow-up survey results part 2

3.2 Staff Perspectives

Working in teams with an industrial partner usually creates excitement amongst students, as it offers the chance of a shared experience and opportunities to gain feedback from someone with alternative perspectives to their lecturer counterparts. It was hoped that by presenting the project in this way, the students would be encouraged to push themselves out of their comfort zones to deliver what was anticipated to be a particularly challenging project. Indeed, students generally engaged well and motivated each other to complete tasks. The involvement of an external design professional helped raise levels of performance and the cohesive nature of group projects helped to promote mutual engagement and team working. Teams were mostly self-selected and so would often coalesce from people who were already socially connected. This benefitted the experience for the team members and typically led to an early decision and a workable project schedule.

While team dynamics can bring significant benefits, they can also present complications. Working as a team applies different pressures and requirements in terms of personalities, opinions, skills, and commitment. If left unchecked, dealing with interpersonal issues eats into the time available and can lead to a rushed or ill-considered design proposal. This became a factor for some teams with the relatively short timescale available and the scale of the challenges they chose to take on. As a result, those teams' final concepts lacked the cohesiveness or depth required to tackle the more subtle down-stream consequences of their proposals in substantial detail.

Undergraduate students can be reluctant to take risks that might result in failure. These cautious tendencies can stifle innovation and are emphasised in teams with a flat organisational structure (as tend to be favoured by most student groups) where direction is often determined more by consensus than vision. The teams were encouraged to think beyond the typical constraints of more familiar design projects, by responding to the brief beyond simply changing materials of an existing product. This required some of them to investigate related issues of distribution, logistics and user behaviour. They were encouraged to consider different models of acquisition and ownership and even whether the product is needed at all or if the solution may lie in a service instead. Their knowledge of these issues or ability to develop a meaningful understanding was recognised as a complexity within the duration of the project.

Across each team a broad range of design skills and use of CAD was evident and their effect on the outcome became very apparent when the final concept was presented. Highly developed skills are not always evenly distributed across all teams. This means that when assessing the work, it was important to see past the visual impact of the presentation resulting from visualisation tools.

Students demonstrated a range of abilities to construct a narrative to describe their proposal well enough to stand up to questioning. It is becoming increasingly essential that design graduates entering industry have developed their own views around sustainability and know how to apply them within the context of a design project. Progress in this area is by far the most beneficial aspect of the project. The reason for this is that qualified sustainability professionals are in demand across all manufacturing sectors to develop informed industrial strategies. The delivery of those strategies will require an appropriate design approach and therefore a design team that knows sustainability needs to be considered throughout a development project, from brief to delivery.

As these students embark on their final year level 6 projects, they go on to identify UN Sustainability Goals [8] that they will aim to address while undertaking their major project. We have seen that, given the opportunity, there is a tendency for students to superficially address these pledges rather than using them as driving forces for innovation. By actively encouraging students to take on these challenges through projects such as that described here and then following up with further support and incentives at level 6, it is hoped they will feel more inclined and able to solve these problems as willingly as they might tackle more typical dimensions such as aesthetics and ergonomics.

4 CONCLUSIONS

Overall, students accept the precarious nature of the current environmental situation. However, many find it difficult to comprehend ways in which they can contribute to solutions in a significant way. A common complaint is that industry places too much emphasis on keeping costs low to be able to pursue meaningful sustainable design solutions that they regard as more expensive. In many cases this view is supported by the commercially available products with which they are familiar and the acquisition cost of alternatives. Despite these current hurdles, the direction of travel appears to be correct and good. Given where undergraduate students are in their careers, it is important that they are given space to consider these issues and topics before they embark further on their professional careers. The project described here has the potential to introduce students to unfamiliar territory in a safe intellectual environment, where risk-taking is encouraged and rewarded rather than stifled in favour of what is deemed feasible in the here and now. It is our belief that only by encouraging design students to influence industry from within as it seeks to respond to and affect human behaviour traits, that we can hope to begin to bring about tangible, long-term changes.

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EDUCATIONAL RESOURCES TO IMPROVE JAPANESE HIGH SCHOOL TEACHERS' FACILITATION ABILITIES IN PROBLEM IDENTIFICATION AND IDEATION ACTIVITIES

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ABSTRACT
This study aims to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the design-based activities in the SDGs Challenge Project. Using a qualitative approach and the SDGs Challenge Project as a case study, this study analysed teachers' feedback before the project started and post-lesson surveys to determine the difficulties teachers have faced in facilitating the design process in 2021 and 2022. The findings showed that teachers have difficulties understanding design thinking, inadequate facilitation skills, limited content knowledge, and unfamiliarity with the worksheets provided. The educational resources for teachers to guide the design process in this project are necessary. The new educational resource should offer knowledge and the methodology of the design process. In addition, resources on pedagogical strategies to facilitate the design thinking is required. Exemplars of student outcomes for each design task and clear explanations of the purpose of each task is also necessary as a resource.

Keywords: Design process, design education, educational resources, problem identification, ideation

1 INTRODUCTION
Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been promoting 21st Century learning and skills-based education [1]. In 2018, MEXT introduced the *Period for Inquiry-Based Cross-Disciplinary Study* for inquiry-based learning. This subject focuses on interdisciplinary and integrative learning to help Japanese students develop 21st Century skills such as critical thinking and problem-solving. The objectives of the *Period for Inquiry-Based Cross-Disciplinary Study* are (1) acquiring problem-finding and problem-solving knowledge and skills, (2) finding real-world problems and research-related information and proposing appropriate solutions, (3) developing independent and cooperative learning [2]. Design thinking has the potential to prepare students to solve future challenges by fostering 21st Century skills. The SDGs Design School in Kyushu University, Faculty of Design, collaborated with Fukusho High School to develop and implement a design-based project called the *SDGs Challenge Project* for all 3rd grade students in 2021. SDGs refer to sustainable development goals promoted by UNESCO (United Nations Educational, Scientific and Cultural Organization). The project adopted the product design process and required the students to solve design problems related to the SDGs. The objective of this project is to develop students' 21st Century skills and awareness of sustainability. The *SDGs Challenge Project* was implemented in the *Period for Inquiry-Based Cross-Disciplinary Study*. The project was designed for 18 weeks, with a lesson duration of 100 minutes per week. A key challenge faced was that various subject teachers are drafted for this project and were not trained in design education. The study aims to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the *SDGs Challenge Project*.

2 LITERATURE REVIEW
The *SDGs Challenge Project* adopted design thinking as key approach towards problem solving in teaching students solve sustainable related problems. This section first provide justification of adopting

design thinking as an approach to teaching problem solving. Then after, the current issues with implementing Education for Sustainable Development (ESD) in Japanese schools will be reviewed.

2.1 The significance of design thinking in Education

Design thinking is defined as an analytic and creative approach to solving wicked problems whose solutions should be solved by multidisciplinary means. It identifies users' needs through iterative cycles of feedback to test and refine prototypes [3]. Adopting design thinking as the foundation for a pedagogical framework in schools has been shown advantages in student development [4]. A research study conducted in Singapore showed that teachers acknowledge the benefits of design thinking in improving students' abilities. Design thinking helps enhance creativity, problem-solving, communication, and collaboration skills. Moreover, it aids in developing empathy and compassion among students toward their communities [5].

2.2 Current challenges of ESD in Japan's school education

As a vehicle for promoting ESD in Japan, schools associated with UNESCO Associated School Project Network (ASPnet) and Super Global High School (SGH) have been integrating ESD into their school programmes. One example is School A, a university-affiliated high school mentioned by Fredriksson et al. [6]. School A is an ASPnet and SGH-designated school that offers integrated courses with a cross-disciplinary approach that provide a variety of electives subjects where students can study. The integrated courses are integrated with ESD concepts to some extent. While School A adopts a multi-disciplinary approach in implementing the programmes, some teachers lacked a clear understanding of ESD concepts. Thus, teachers' commitment to the ESD programme was different.

In one of the Learning Innovation (未来の教室) projects, Sakaki High School and Karuizawa High School in Nagano Prefecture collaborated with Life is Tech (an IT and programming education service company) to implement a problem-solving project in the Period for Inquiry-Based Cross-Disciplinary Study [7]. Some objectives of the project are to develop students in problem-solving and awareness of sustainability. Some key issues surfaced in this collaboration between industry and schools. The training and involvement of teachers other than the teacher in-charged remained a work in progress. For the two schools to run the programme by themselves, they will have to address the needs of teacher training, usage of teaching resources for the project, technical support, collaboration with external personnel, etc. The cases above provided examples of implementing issues for problem-solving projects related to sustainable development. As an example, the current study on the SDGs Challenge Project can be a valuable case study for public high schools seeking to implement sustainable related problem-solving projects in their school programmes.

3 RESEARCH METHODOLOGY

The research question for this study is set as follows: What difficulties do teachers face in the design process when facilitating the *SDGs Challenge Project*? The study employed a qualitative research approach using the *SDGs Challenge Project* implemented in the *Period for Inquiry-Based Cross-Disciplinary Study* in Fukusho High School as a case study. Quantitative and qualitative methods for data collection were used. The study participants were teachers facilitating the project in 2021 and 2022. In 2021 and 2022, 27 teachers were involved, respectively. Some of the teachers in this project were again involved in 2022. In this project, students were tasked to find problems in their daily lives and relate them to SDGs. After selecting a problem that they were interested in, students researched to understand the problem. Through the design thinking process, students then generated ideas to solve the problems. There were no restrictions on the kind of solutions students could propose. Teachers involved in this project were from different subject backgrounds and were not trained to facilitate design thinking activities. As Fukusho High School is a public and non-specialist school, as such, subject teachers are not trained to teach design. Teachers with some knowledge about design are art teachers where students learn some form of design during art lessons. Refer to Table 1. Various instructional resources were provided to support teachers in facilitating the project. Refer to Table 2. An example of worksheet used by students is shown in Figure 1.

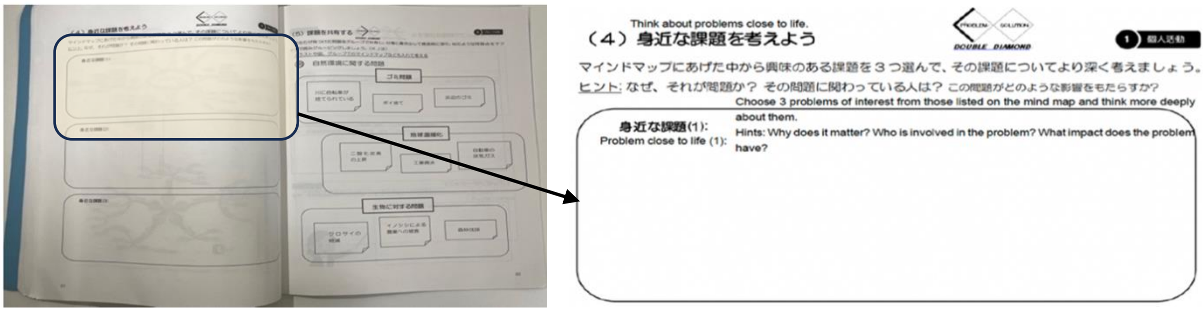
A pre-project survey is conducted before the start of the project, and post-lesson surveys are conducted after each lesson, from lessons one to seven, which cover the problem identification and ideation stage in the design process. The types of questions and the rationale for the pre-project and post-lesson surveys are shown in Table 3. The Likert scale items 1 (Not at all) to 5 (extremely high) and open-ended questions are used in the survey. The Likert items are analysed using descriptive statistics. Open-ended responses were analysed, categorized, and interpreted to look for connections in teachers' perceptions.

Table 1. The profile of teachers who participated in the SDGs Challenge Project

Years	No. of Participants	Subjects	Teachers who participated twice
2021	27	Japanese Language (5), Mathematics (2), English Language (4), Social Studies (5), Science (4), Health and Physical Education (4), Arts (1), Home Economics (2)	0
2022	27	Japanese Language (5), Mathematics (3), English Language (4), Social Studies (2), Science (1), Health and Physical Education (3), Arts (2), Home Economics (2), Business (5)	10

Table 2. Types of instructional resources provided to support teachers

Resources	Type of resources	Resources objectives
Online Resources	Explanation videos	Explanation of the design process and design methods.
	Pre-lesson slides	Providing teachers with an overview of each lesson's content.
	Post-lesson slides	The coordinator created slides to answer the questions the teacher had in the questionnaire after the lesson.
Paper Resources	Lesson plans	Providing an overall summary of the project and outline the tasks that need to be completed in each lesson.
	Student worksheets	It offers teachers and students a form in implementing the tasks. Teachers need to teach from the worksheet section and the students need to fill in the tasks in the worksheet in class.



(a) (b)

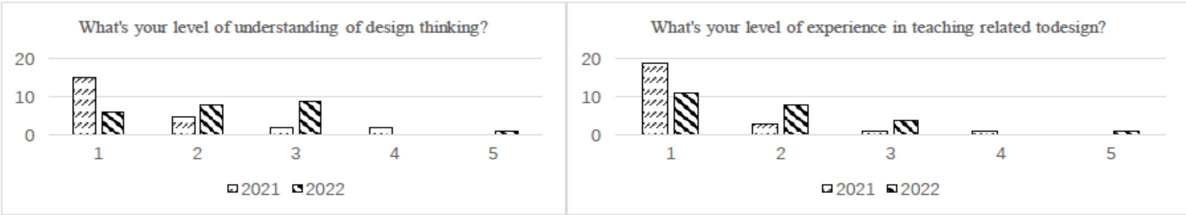
Figure 1. (a) An example of the student worksheet booklet provided to students; (b) A more detail view on part of the worksheet where students write down the problem their identified

Table 3. Question types and rationale of questions in the pre-project and post-lesson survey

No.	Question types	Questions in Pre-project survey	Reasons for setting questions
1	Likert scale items, 1-5	What's your level of understanding in design thinking?	Finding out whether design-based activities can be advanced when teachers do not have design education experience before.
2		What's your level of experience in teaching related to design?	
3	Close-ended question	What's your main subjects?	Collect the basic information about the teachers.
4	Open-ended question	Please write down your concerns when SDGs Challenge Project is implementing.	Discover what concerns teachers without design education have before conducting the project.
No.	**Question types**	**Questions in Post-lesson surveys**	**Reasons for setting questions**
1	Open-ended questions	Please describe any difficulties you have had in facilitating.	Finding out what difficulties teachers without design education have in facilitating design-based activities.
2		Please write down if there are anything you want the coordinator or teachers at K University to support you in next week. Or suggestion.	

4 FINDINGS

In the pre-survey, 24 responses were received for 2021 and 2022, respectively. The responses collected are presented in Figure 2. Regarding the understanding of design thinking, teachers who indicated that they had no understanding of design thinking were much lesser in 2022 than in 2021. Teachers who indicated they slightly understood design thinking increased in 2022. However, very few teachers perceived that they had a good understanding of design thinking. Regarding teaching experience, similarly, teachers who perceived that they had no experience in teaching related to design had decreased in 2022 compared to 2021. In addition, teachers who perceived they had little teaching experience in design increased in 2022. However, very few teachers indicated they had rich teaching design experience. Table 4 shows the teachers' concerns about the design process in 2021 and 2022. From the teachers' feedback, their concerns were categorized into key concern factors. In terms of lacking content knowledge about the design, teachers' concerns include the lack of understanding of design thinking and concrete implementation of design activities. Feedback related to not knowing how to monitor progress, anxiety about supporting and facilitating the students, unsure of facilitating students and fear of interfering too much were considered a lack of facilitation skills. When teachers responded that they lacked knowledge of the project, were inexperienced with the project, and lacked understanding of the project, these concerns were categorized as unaware of the project's content.



(a) (b)

Figure 2. (a)Teachers' level of understanding of design thinking (b) teachers' experience in teaching design thinking

Table 4. Teachers' concerns of the design process during the project in 2021 and 2022

Q: Please write your concerns when SDGs Challenge Project is implemented.		
Years	Concerns about design process	Key concern factors
2021 (n=24)	• Lacking in the understanding of design thinking. • The extent that teachers will be involved and how they monitor progress when facilitating the project. • Lacking knowledge of the project and anxious about facilitating. • Anxious about supporting and facilitating the students. • Fear of interfering too much with students and unsure of facilitating students. • Concrete implementation of the design. (Problem identification.)	• Lack of knowledge about the design process. • Lack of facilitation skills. • Unaware of the content of the project.
2022 (n=24)	• Although participated once before, still lacked an understanding of the design process and was unsure of facilitation and pedagogical skills. • In-experience with the project and am anxious about facilitating. • Lacking the understanding of the project.	

Table 5. Difficulties of design process teachers had from Lesson 1 to 7 in 2021 and 2022

Design Process	Lessons	Teachers' difficulties related to the design process from Lesson 1 to 7 in 2021 and 2022	
Problem Identification	Lesson 1 Students are divided into groups; Exploration of problems and sharing.	2021 (n=17)	• Do not know how to advise students when they are confused. • Teachers were unaware of the assignment done by students. • Students do not understand the KJ method despite having been taught them.
		2022 (n=17)	• Guiding students to narrow down the problem. • Students don't understand the tasks in the worksheet. • Teachers lacked critical thinking to select useful information.
	Lesson 2 Selection of problem; Refine the identification of the problem	2021 (n=21)	• Lacking facilitation skills. • Students were not active in group work and lack motivation. • Lacking the understanding of the problem identification process. • Unclear about the instruction of the worksheet provided. • Students were not able to connect the concepts. • Need for teachers' guidebook with examples and model answers.
		2022 (n=9)	• Teachers need more examples in the worksheet. • Unclear about the instruction of the worksheet provided. • Seek help from the design faculty member.
	Lesson 3 Research on a selected problem	2021 (n=16)	• Difficulties in monitoring students' progress • Seek help from the design faculty member. • Students lacking in research skills. • The students 'interest level was different.
		2022 (n=13)	• Unclear about the instruction of the worksheet provided. • Not knowing the time to intervene in student discussion. • Students lack research methods. • Different progress among different groups. • Seek help from the design faculty member.
	Lesson 4 Sharing findings; Identification of targets related to the problem	2021 (n=17)	• Difficulties in determining the target users and stakeholders. • Difficulties in providing advice to students. • Students were not active in group work and lack motivation. • Difficulties to choose the problem and come up with a specific solution. • Seek help from the design faculty member.
		2022 (n=7)	• Guiding students to discard preconceptions and find the problem.
Ideation	Lesson 5 Research on existing solutions	2021 (n=13)	• Difficulties in determining the target users and stakeholders. • Students lacking in research skills.
		2022 (n=5)	• Nothing in particular.
	Lesson 6 Ideation	2021 (n=13)	• Guiding students to generate detailed ideas. • Seek help from the design faculty member. • Teachers provided too much advice. • Lacking teaching strategies and understanding of design process.
		2022 (n=4)	• Asking the question to students about their problems. • The students 'interest level was different. • Students cannot understand the meaning of target users.
	Lesson 7 Selection of ideas; Poster making	2021 (n=9)	• Guiding students to generate creative solutions. • Unclear how to create the concept poster for solutions.
		2022 (n=5)	• Expect more opinions from design faculty members. • Different progress among different groups.

From each post-lesson survey, the challenges teachers faced in the problem identification and ideation stage and the number of responses is presented in Table 5. The key challenges faced by teachers can be summarized as follow. During problem identification, teachers lacked understanding of the process. They found it difficult to guide students to narrow the problems into specific details, and they sought help from members of Kyushu University. Teachers also faced challenges in advising students in problem identification and monitoring students' progress as some students lacked motivation in their work. Regarding the worksheets, teachers mentioned that the instructions in the worksheet were unclear, and students did not understand the tasks required. Teachers also suggested having a guidebook with examples and "model" answers for the tasks in the worksheet. Lastly, students lacked research skills and faced difficulties determining the target users and stakeholders.

In ideation, teachers struggled to guide students to generate creative solutions and detailed ideas. Some teachers provided too much advice or found it difficult to guide students in the ideation process, thus displaying the possible lack of teaching strategies. Some teachers lacked understanding of the designing process and sought help or opinions from members of Kyushu University. Teachers were also unclear on how to create the concept poster for the solutions. Lastly, teachers found that students lacked research skills in the ideation process.

5 DISCUSSIONS AND LIMITATIONS

From the pre-project survey, an indication of an increase in the level of understanding in design thinking and related teaching experience may be attributed to the availability of instructional and online resources in 2021. Also, considering there were teachers who participated twice, this suggested that repeated participation may familiarize teachers with the design process. However, many teachers still indicated little understanding of design thinking and related teaching experience. Perhaps, explanatory notes on how to use the worksheets, and lesson videos showing exemplary teachers who had facilitated the project well may be required as a form of resource. While conducting professional development for teachers before the project start may be useful [8], teachers can also practice self-reflective exercises after every lesson to reflect on good and bad practices as a form of learning to improve teaching and learning skills [9]. While a briefing session was conducted before the project, it is good to create opportunities for "experienced" teachers to share knowledge with teachers who newly joined the project.

Teachers' key challenges in the problem identification and ideation process are as follows. First, teachers may lack facilitation skills and may be attributed to being used to using teacher-centred approach. They are often not sure how to advise or when they should provide answers. Teachers may address facilitation issues by using questioning techniques to guide students to surface problems [10]. Second, teachers may lack sufficient understanding of the problem identification and ideation process. Thus, teachers were unable to give students timely feedback on their questions and monitor students' progress. They faced difficulties advising students to narrow down the problem and guiding them to generate creative and detailed ideas. Third, teachers may lack content knowledge and skills to help students to complete the tasks required in problem identification and ideation. In the design process, different groups of students will require different knowledge and skills to engage in different design problems. When students lack research methods and have difficulties determining the target users and stakeholders, teachers are unable to guide students to accomplish their goals. The reason may be related to teachers' lack of the content knowledge and skills required to facilitate different groups of students working on different problems. Fourth, teachers were not involved in creating the worksheets and may subsequently led to a lack of understanding of the use of the worksheets. Some teachers did not understand the necessity of some activities. Perhaps teachers' involvement in designing the worksheets are necessary.

Several key interventions may be suggested to address teachers' challenges. Professional development to train teachers before the project will be necessary. However, providing professional training can be hampered by constant personnel changes and time constraints. Teachers are rotated to other schools about every 5 years. Incoming and outgoing of teachers often occurs close to the new academic year, this poses significant challenges to finding the best time to conduct professional training. Instead of organizing professional training, providing timely educational resources for teachers to facilitate the project may be a more feasible solution to address their difficulties.

Teachers need to consider the learning content, pedagogy, experience of learning, tone of the environment, and assessment when planning lessons to raise engagement in the classroom [11]. Some teachers may also lack the necessary pedagogy and learning content. When designing a set of educational resources for the project, the considerations are as follow. First, resources should include students-centred teaching strategies, such as questioning techniques, to help teachers facilitate the activities. Second, resources should support teachers' understanding of problem identification and the ideation process. Understanding the design process will allow teachers to understand that design problem is ill-defined and that solutions are unlimited. Hence, teachers may be able to monitor students' progress and give timely feedback. Third, resources are needed to support teachers' knowledge [12]. Resources should also contain the content knowledge and skills to help teachers guide students to complete the tasks. Moreover, resources should also inform teachers of the reasons for each task. Lastly, exemplars are necessary for teachers to know the expected outcomes of students' activities.

The limitation of the study is that in 2022, the number of teachers who responded to the 2022 post-lesson surveys was much fewer than in 2021. As such, we could only analyse the difficulties faced by teachers who had responded to the questionnaire. Additionally, there is a lack of clarity on the specific targets and benchmarks that students should aim for in their solutions. In general, students present policy related proposals or technological innovations as part of their ideal solutions.

6 CONCLUSIONS

The purpose of this study is to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the design-based learning activities in the *SDGs Challenge Project*. It can be suggested that educational resources for teachers are necessary. The following aspects should be considered for the educational resources: First, it should have teaching strategies to guide student-centred learning. Second, it should include knowledge of the design process and design method. Third, the worksheet should be redesigned and introduce the meaning of the tasks in the worksheet. Lastly, exemplars should be provided in the educational resources for teachers to know the expected outcomes of students' activities.

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BEYOND DESIGN AND PLAY; GAGING A RESPONSIBLE PATH FOR DESIGNING THE FUTURE

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ABSTRACT
Designers draw inspiration from the societal needs around them. In Design Education, a continuous effort is being made to assess the potential personal, social, health and environmental impact of a design in its early stages. To add to this body of knowledge we updated the Future Scenario Development, Play and Design methodology. This scenario development approach aims at exploring futures that are more than just a few years ahead of us. In the master course Create the Future, the students follow this approach to develop a future context for their own conceptual design phase. When they subsequently design for their own future, we want to make them aware of the multifaceted effects of their designs. We therefore expanded the method to include responsibility and societal influence assessment tools such as the Product Impact Tool (PIT), and Constructive Technology Assessment (CTA).
With a case study, based on the results of an Industrial Design Engineering Master course concerning the design of the “Future of Healthcare”, we will show how this Design of the Future methodology is able to explain the present and future interplay between society, culture, and technology. We will especially dive deeper into the experiences with the assessment tools and how they influenced the design phase and eventually the design concepts presented by the students.
From the results of the case study, we can conclude that our proposed method provides the students with an effective arsenal of tools through which to envision, reflect and design for the future.

Keywords: Responsible design, futuring, scenario development, product impact, technology assessment, healthcare

1 INTRODUCTION
In recent years with the emergence of new epidemics and public health crisis (COVID, obesity, sedentary behaviour, etc) it has become glaringly obvious that global cohabitation needs to account for global and local health. The health of humanity and the environment have shown to be also strongly correlated, making sustainability and health sister-challenges. At the same time, many societies are ageing, especially in Europe and North America, bringing forth new cohabitation challenges. Designers and engineers are called to work on wicked problems that involve a plethora of actors and require not only effective but also accessible, equitable and responsible innovations [1].
Concurrently, challenges related to large and complex issues such as health and cohabitation are future oriented. Any attempt at innovating within those contexts will have an impact on the future of our society. Designers and engineers are called to create responsibly, considering possible future implications of their decisions [2]. Therefore, tools to explore possible futures, learn from them, and apply findings to new designs will be very useful.
Given the uncertainty that any discussion about a pluralistic future involves, we propose an extension of the Future Scenario Development Design & Play method (FSDDP) [3] which aimed at helping designers vividly explore the interplay between Society, Culture, Economy and Technology in potential futures (which itself evolved from the Future Scenario Development method [4]). By using a combination of scenario building, tangible exploration, and practical design, the method helped students to expand future scenarios to their full social, economic, and environmental implications. As the next step to this method, we implemented the use of design tools such as the Product Impact Tool (PIT) [5] and Constructive Technology Assessment (CTA) [6]. This new method helps to implement learning points from the exploration phase into designs and evaluate the responsibility of said designs. In this paper we will argue that this method helps in creating more responsible designs.

In addition to our method, we present a case study, based on the results of an Industrial Design Engineering Master course concerning the theme “Future of Health”. Health as a broad topic is interconnected with human cohabitation and sustainability. On a macro level human health is connected to zoonotic diseases, climate change, pollution, and population density, while on a micro level personal health and access to quality healthcare are needed for people to achieve long and fulfilling lives. On a meso level there is big disparity between different communities’ access to health services but also their culture and preferences regarding health. This subject is therefore an excellent case to discuss how we can design responsibly considering the future interplay between Society, Culture, Economy and Technology.

2 METHODS

The Future Scenario Development Design & Play method [3] is a seven-step process we use to define, research, and explore an issue. The method involves defining a focal point, listing the relevant actors and factors, identifying the most relevant and uncertain factors (uncertainty & relevance matrix), developing scenarios based on the potential developments and exploring these scenarios using a serious game (Scenario Exploration System, SES [7]) followed by a practical designing part. The play aspect of FSDPP, the Serious (SES) Game, is fully described in [3] and will not be a prominent aspect of the expansion work of this paper.

Table 1. Expanded method of the FSDDP method

Step 1-7	Scenario building and exploring	Steps as detailed in [3] include: Focal Issue - Actors & Factors - Uncertainty/Relevance Matrix - Strategic Space - Scenario Plots - Scenario Elaboration - SES game Session.
Step 8	Future Concept Design	Design a Product, Service, PSS, or other Artefact for one of the explored futures in step 1-7.
Step 9	Product Impact Tool	Analyse the designed artefact to assess what kind of impact it could have on humans, society, and the environment.
Step 10	Constructive Technology Assessment	Analyse the dynamics at play in future product development cycles.
Step 11	Innovation Journey	Propose a way to introduce the artefact in society, creating an iterative (technology) development process using societal dialogue.

Based on our previous experiences with the method we concluded that some way to structurally address responsibility would be useful. While the previous method had an extensive library to address a need in a future society and fit in this context, it did not include any tools ensuring the design would be introduced in a responsible way and considering a broader range of stakeholders. Using well defined tools while designing for a future/unfamiliar context can help to avoid adopting preconceived notions and our current understanding of the world, which we seek to challenge.

There are several tools aiming to foster responsible design, such Design with Intent [8] and Socially Responsible Design [9]. In addition, there are many tools that investigate how to introduce a future technology, not limited to several forms of Technology Assessment [10], Roadmapping [11] and Technology Forecasting [12]. We chose to enhance our FSDDP by adding the Product Impact Tool, Constructive Technology Assessment, and Innovation Journeys, because of our prior experience with them, successful use in previous courses at the University of Twente and their well-complementing fit, expanding the method to a total of 11 steps (see table 1).

2.1 Product Impact Tool

The Product Impact Tool[1] [5] is a tool developed to help designers see what kind of impact a new design could have on humans, society, and the environment. The tool does so by highlighting different modi of interaction that could arise with newly developed products and gives a qualitative outline of these

[1] https://productimpacttool.org/en/

processes [13]. This makes it especially suitable for responsible design studies [2, 14]. The tool offers a substantial overview of sample effects technology could have on people, complete with examples, which can be very helpful for students and novel designers [15].
After creating a first version of their design, the students used the PIT to engage in ethical reflection over their design decisions and evaluate the desirability of potential behaviours that their innovation could create. They then used the tool to redesign their initial concept to account for any findings they had regarding usability, acceptance, and/or behaviour change, by transforming effects to different PIT quadrants.
In that way the students examined their inventions "from all sides" - using the four modes of impact presented in the tool - and took steps to make sure that they were as responsible as possible. The resulting product designs would continue to be the subject of the CTA analysis aiming to produce a well-rounded value proposition with respect to societal fit and responsibility.

2.2 Constructive Technology Assessment & Innovation Journey

The method of Constructive Technology Assessment [6] was invented to address society's response to new technologies. While "classic" Technology Assessment assumes designed technology as a given, CTA opts for an iterative process of technical change where society co-produces the technology with the innovators [16]. This is done by collecting feedback from users and societal actors during introduction of the technology, allowing for a more responsible introduction.
We introduced the concept of CTA to the students by starting with a 4-hour guest lecture about CTA & Innovation Journeys from Prof. Dr. Stefan Kuhlmann, one of the key contributors to CTA research in the past decades. This lecture aimed to quickly acquaint the students with the societal intricacies that the introduction of a design may bring about in the future, prompting them to make use of these dynamics in their design. Next, we tasked the students to do an assignment on CTA.
We wanted to simulate some similar outcomes as a CTA stakeholder workshop but decided to set it up in a different way. Our decision was based on three factors; the existing timeframe and workload of the course, CTA workshops being run in other courses, and the fact that, by definition, any participants in these workshops would be decades detached from the intended end user of the product. Through the SES in the Design & Play method, the students already had quite some experience empathising with the future user group, and enhanced with the insights of the PIT tool, we let the students speculate on possible outcomes of such a workshop with four envisioned main stakeholder groups. Taking the outcomes into account in the further design iteration. The explicit analysis from the PIT tool could fill in the gap of bringing the new perspective of the user groups not being present.
The CTA method was continued by using the concept of Innovation Journey's [17]. In this method, designers consider the dynamics in which technologies are introduced in society, by looking at different loci -protected, controlled, spaces in different regimes- to introduce products using (parts of the) technology. This caters to an iterative technology development process, using feedback loops to allow for groups of users and social actors to have an influence on the final technology that would be released to a wider public. This method was used to let the students think beyond their final product proposition itself and to include ways of how to introduce a designed artefact responsibly in society.

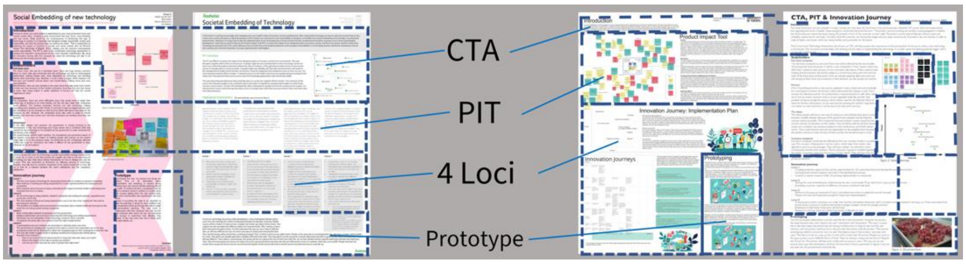

Figure 1. Four examples of results of the CTA and PIT tools

The students were tasked to use the concept of Innovation Journeys to devise a method of carefully introducing the technology in different regimes, in different future time horizons, to foster the iterative dialogue between product designers, users and society. Next, they envisioned what a low-fidelity prototype that can be used in today's world would look like, in order to test how users would respond to the technology before it was developed. To help facilitate this process, examples were provided of

fast-prototyping methods, such as the wizard-of-oz technique. Testing the prototype was however not within the scope of the course.
Finally, students used the findings of steps 9-11 to improve their design. They accompanied their final design with a one-pager (see Figure 1) on the effect their product may have on users, using the insights from the PIT tool, the stakeholder analysis for CTA, and the three loci from the Innovation Journeys.

3 CASE STUDY

The way we approach and manage health is strongly influenced on a human level by the relationships and interactions we build in our society. Additionally, it is strongly interconnected with environmental factors, social dynamics, economy, law and technology. Being such a complex and important topic, health is an excellent carrier for the investigation of the future interplay between Society, Culture, Economy, and Technology. As medical technology is developing and steadily enters our everyday lives at an increased pace, it demands more responsible approaches both during its design and development.
The future of Health was investigated within the master course Create the Future. The course itself was set out as project-oriented education [18], arranged around the theme of Health. It lasted ten weeks and had the workload of five European credits. The course followed our FSDDP structure as outlined in table 1. It was split into two sections, starting with building future scenarios (step 1-6), followed by a mid-term presentation, exploring the future in the SES game session (step 7) and the development of design concepts within these future scenarios (step 8). In the finalising phase of the course the students used our suite of tools to analyse and improve the social responsibility of their future design concepts. Sixty students took part in the course organised in twelve groups, resulting in twelve unique designs from which we have selected the two presented here. The course was complemented by a collaboration with Nedap, a local industry leading Medtech company, who provided feedback throughout the course.

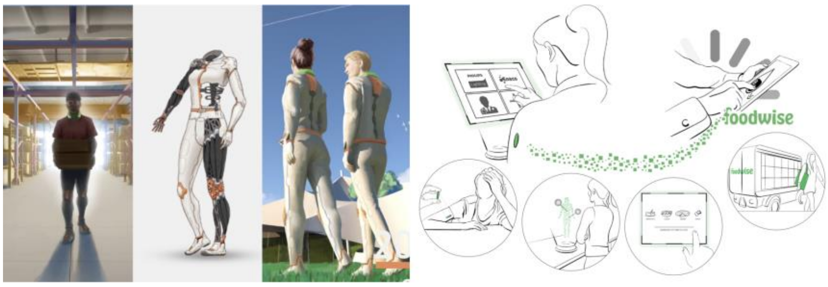

Figure 2. Left: EMPOWEAR rehabilitation suit, by G. Dzhondzhorova, L. van den Berg, R. Spaargaren and S. Zhao; Right: Foodwise health service system for women, by A.R. de Gooijer, J. Scheeper, N. Kaldenbach, V. Jansen and T. Nguyen

3.1 Design Example 1: EMPOWEAR

In this project the students decided to focus on rehabilitation (see *Figure 2 - left*). Their focal issue was described as "How will the future of physical rehabilitation, specifically in using part of the body or coping and relearning to live with a physical disability develop in 2052." The scenario they chose to use is characterised by an increasing number of accident survivors, the health sector's move towards home rehabilitation and the lack of human resources.
Aided by the scenario's opportunity for technology to aid healthcare and the projected development in robotics the students came up with a wearable rehabilitation suit. Using the PIT tool, they managed to identify new potential effects. For example, battery life dependence, potential loss of autonomy and issues with combining extreme temperatures and necessary wearable technology. Addressing these findings impacted the initial design, by for example adding maintenance/charging hangers and designing the exoskeleton to weaken over time to avoid dependence. Other more serendipitous findings also included economic and environmental sustainability. The students realised that these expensive suits would be useless to the owner after recovery, while maintenance cost could prohibit ownership for some people. By designing the procurement of a suite to be insurance covered and doctor-issued rentals the students addressed both issues. By visualising the future applications of the suit through CTA the students discovered new user groups in niches that would allow for testing, e.g., professions facing high accident risks could use the suit preventatively. Finally, taking into consideration potential misuse, they included legislation such as classifying the suit as medical equipment.

3.2 Design Example 2: Foodwise

In this project the students decided to focus on investigating how diagnostic care can develop from its current male-centric state (see *Figure 2 - right*). Their focal issue was stated as: “How will female diagnostic healthcare develop in the Netherlands?”. Focusing most on government involvement and potential technological innovation, the students created three different scenarios as a potential future context. They chose to design for the future scenario in which technological innovation is playing a decisive role while diagnostic female research remains underfunded.

Aided by ubiquitous technology existing in the Dutch homes of 2052, as well as sensors embedded in human bodies, the students designed Foodwise: A service provided to women who wish to take control of their own health through data collection and nutrition. The design was a system that used embedded sensors, a home hub and a meal/vitamin kits service.

Using the PIT the students discovered new potential effects of their product, for example people losing food/cooking related skills and becoming dependent. The students provided a potential solution by adding an education module regarding food, nutrition, and ingredients in the designed app.

Additionally, through the CTA and Innovation journeys the students developed a roadmap for ensuring a smooth adoption of their system. Involving medical research, tech companies and women representation groups, they envisioned a steady progress from small protected and controlled user groups to wide acceptance. Overall, the students built a more well-rounded service covering aspects such as governmental involvement, impact on the socioeconomic gap and potential adoption issues.

4 DISCUSSIONS

It is important to note that in the duration of the course five new tools and methods were introduced and quickly applied by the students. Although many tools were used and adapted to fit together, at risk of the individual value of each tool getting lost, and despite the educator’s worry that the load might be excessive, the students overall showed a good level of understanding and managed to apply the tools well. It helped that the developers of the tools checked our application case to ensure the academic value. Nevertheless, some teams misinterpreted one or multiple tools. Notably, for CTA some students adopted the method of technology forcing or assumed that users are willing to adapt, instead of catering for an iterative introduction process. This distinction would be useful to emphasize beforehand.

The tools’ impact is sometimes hard to distinguish in the final product. Although after a thorough investigation of the arguments in the students’ project reports on why certain elements were chosen instead of others, the influence becomes apparent. In our experience the added tools rendered more thoughtful approaches to address the analysed (negative) side effects. In the previous years these negative consequences were often addressed quite superficially in comparison [14]. It is therefore our opinion that the final designs and the design process became more responsible and robust. The specific impact of each tool can be explored in future research. We assume that providing an arsenal of tools to the students will be helpful in their learning process, and we theorise that with experience their future application of the tools will show a better understanding thereof. For courses constrained on time, a curriculum introducing fewer tools may be more viable.

Due to the large volume of steps to complete and subsequent time limitations most of the workshops and tools were executed by the design teams themselves. The students have however been instructed that real stakeholders would be necessary to truly harvest the opportunities provided by the tools. Additionally, the course collaboration with the company Nedap provided the students with a valuable real-life perspective from experienced designers, sharing their insights on common user reactions towards products.

Another interesting finding is that some groups of students included some extra ethical and critical considerations in their design, beyond the tools. It is possible that the use of the tools guided them towards more critical thinking patterns. Though this result could also be explained by the individual students’ natural predisposition.

Finally, tools such as PIT, CTA and SES are not used for nor claim to eradicate personal bias. Nor are they used to predict the future with precision. They merely aid designers in thinking outside their current patterns/beliefs and to consider the potential political, social, and systemic implications of their designs.

5 CONCLUSIONS

The enrichment of the Future Scenario Development Design & Play method with three additional tools for assessing the societal consequences of future concept designs led to more responsible results of our course “Create the Future”. Next to that, the introduction and swift application of several different tools provided the students with an artillery of options that they can choose to draw from in the future.

ACKNOWLEDGEMENTS

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CHALLENGES OF TEACHERS TO INTEGRATE ESD DESIGN ACTIVITIES IN TECHNOLOGY EDUCATION IN JAPANESE PUBLIC JUNIOR HIGH SCHOOLS

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ABSTRACT
The study aims to clarify teachers' challenges in Technology Education (TE) when implementing Education for Sustainable Development (ESD) design activities into the curriculum in Japanese public junior high schools. The current research is conducted as a case study. The main participants of this study were four TE teachers currently teaching in public junior high schools in Nara City, Japan. A questionnaire survey for TE teachers and a field survey were conducted. According to the findings, the main barriers faced by teachers are a low understanding of ESD and design, low motivation to implement ESD design activities, insufficient teaching materials, and limited teaching time, which prevent TE teachers from integrating ESD design activities into the curriculum as new learning content. A suggestion proposed is that the current TE curriculum can be redesigned through project-based learning (PBL) to regroup and integrate all the learning contents into ESD design activities. Therefore, this study provided a possible new framework for redesigning a new TE curriculum.

Keywords: Design learning, design activities, education of sustainable development, sustainability, technology education

1 INTRODUCTION
In the 21st Century, many environmental, economic, and social problems threaten sustainable development. At the 2002 World Summit on Sustainable Development, Japan put forward the concept of ESD. ESD requires learners to find and solve issues related to sustainability to achieve sustainable development goals (SDGs) [1]. In Japan, the MEXT (Ministry of Education, Culture, Sports, Science, and Technology) has put ESD into the latest national syllabus, including TE. Currently, few TE teachers have integrated ESD into the curriculum. One of the reasons is that many do not know how ESD can be integrated into the TE curriculum [2]. One of the ways to integrate ESD into the TE curriculum is through product design-related activities [3]. This study refers to such product design-related activities as ESD design activities. ESD design activities require learners to find, think and solve real-world issues related to sustainability through the design thinking process, especially the issues related to SDGs. Through ESD design activities, students can improve their awareness of sustainable development.

TE can be associated with Design and Technology (D&T) and Design Education, offered as a subject in the school curriculum in some countries, such as Singapore, England and Australia [4]. In these countries, students learn technical knowledge and skills and apply them to product design solutions. In Japan, TE as a form of general education is mainly conducted in junior high schools, focusing on technical knowledge and skills, with almost no elements of design learning activities, compared to overseas [5]. The latest national syllabus in Japanese secondary education now requires teaching design thinking in TE to improve students' problem-solving skills [6].

The current research is conducted as a case study. The main participants of this study were four TE teachers who are currently teaching in public junior high schools in Nara. This study aims to clarify TE teachers' challenges when implementing ESD design activities in the TE curriculum. The value of this study will provide insights for TE teachers in Japanese public junior high schools to explore how ESD can be implemented in TE curriculum through product design-related activities.

2 LITERATURE REVIEWS

UNESCO (United Nations Educational, Scientific and Cultural Organization) shows that ESD is not simply an extension of environmental education but a catalyst for change and a way of addressing the changes in values and behaviours required for a sustainable future [7]. It involves learning how to make decisions to balance and integrate the long-term future of the economy, environment, and society [8]. ESD aims to cultivate one's qualifications and abilities as the founder of a sustainable society by requiring learners to treat global issues as their problems and take action to solve them [9].

TE is a learner-centred and interdisciplinary subject that provides students the opportunity to actively think, find and solve open-ended problems [10][11]. In some countries, such as Europe, North America, and Australia where ESD has been developing in TE through product design-related activities from elementary to higher education, which can be viewed as ESD design activities. Based on the available literature, the key characteristics of ESD design activities in TE may be presented as follow:

- Design problems are open-ended problems, being set within a social-economic-environmental framework, tending to focus on solving environmental problems [12].
- The theme of design activities in each country's TE focuses on different dimensions of sustainability because policies and development priorities differ from country to country [13].
- Besides developing the cognitive dimension of learning, the development of social and psychomotor skills, as well as effective attributes, such as the responsibility of sustainable development, tolerance, and teamwork skills are emphasized [14][15].
- Participatory learning and higher-order thinking skills are promoted, such as critical thinking, creative thinking, and problem-solving skills [16][17]. Also, students can develop the ability to plan, execute and evaluate [18].
- Eco-design principles are used, emphasizing the utilization of low-cost, long-term using, renewable sustainable technology to design sustainable products and services [19].
- Caring for cultural diversity. Traditional technologies are important components. The connection between sustainable development with regional social and culture is considered [20].

Yatagawa and Kurishima showed that only 4% of the junior high schools in Japan develop ESD well, most of which are ASPnet (UNESCO Associated Schools Project Network) or university-affiliated junior high schools [21]. In public junior high schools, ESD has yet to be actively implemented. In TE, more than 80% of teachers are motivated to integrate ESD into the curriculum, but they have met lots of problems cause that ESD did not develop well in TE, such as 1) teachers have no deep understanding of ESD; 2) lack of appropriate ways; 3) lesson time is not enough; 4) lack of effective evaluation methods. The main teaching objective of TE in Japanese junior high schools is to cultivate technological literacy, focusing on learning basic technical knowledge and skills. Currently, in Japan, "Design" in TE focuses more on production-making than real-world problem-solving [22].

3 RESEARCH METHODOLOGY

In this study, the main research question is as follow.

- What barriers do TE teachers face that prevent them from conducting ESD design activities in the existing TE curriculum?

The current study was conducted as a case study. In this case study approach, quantitative and qualitative data were collected and used. The main participants of this study were four TE teachers teaching in public junior high schools in Nara. The considerations for selecting the four teachers were based on the followings: 1) most junior high schools in Japan are public junior high schools, thus the issues faced by the four teachers may resonate with teachers in other public schools; 2) the four TE teachers are motivated to integrate ESD design activities into existing TE lessons. The four TE teachers have different numbers of years of teaching experience. Refer to Table 1.

Table 1. Teaching experience of the four participating TE teachers

Participants	Teacher A	Teacher B	Teacher C	Teacher D
Years of teaching experience	About 10 years	About 8 years	About 1 years	Less than 1 years

The study objects came from questionnaire surveys done by the teachers. The questionnaire consisted of 12 open-ended questions to clarify whether teachers have done anything related to ESD design activities. Teachers who have conducted ESD design activities in their lessons are required to answer

Q2 to Q8. Q2 to Q8 mainly clarifies 5 areas: 1) the curriculum arrangement of ESD design activities; 2) educational objectives and student outcomes; 3) assessment methods; 4) problems teachers faced, and 5) expected student outcomes. Teachers who have not carried out ESD design activities would answer Q9 to Q12. Q9 to Q12 mainly clarify 3 areas: 1) the reasons for not doing ESD design activities; 2) the approaches they may take to solve the problems faced; 3) the expected educational objective and student outcomes of ESD design activities. Refer to Figure 1. The open-ended questions are analysed by first reading and reviewing the data. Then, the responses are categorized and interpreted to look for links and differences in teachers' perceptions. To supplement the questionnaire survey, a field survey was conducted. Permission for the field survey was given by teachers A, B, and C. The main purpose is to clarify further the type of teaching and learning activities, learning environment, and issues related to ESD design activities that may not be surfaced in the questionnaire survey.

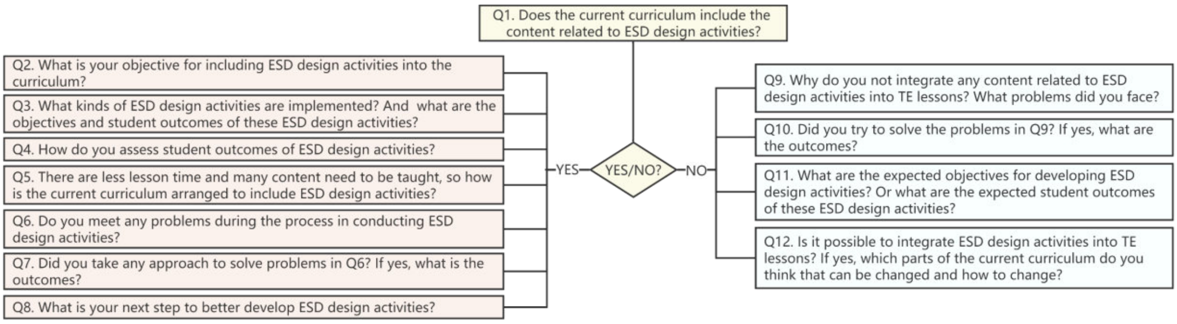

Figure 1. Open-ended questions in the questionnaire survey

This research was implemented in September 2022. Before the questionnaire survey, an explanation session was conducted to explain the different types of product design-related activities that can be conducted in TE to give the teachers a clear idea of what product design-related activities in TE are. At the same time, the definition of ESD design activities was explained. After this session, teachers were given a questionnaire survey to answer. In addition, a field survey was subsequently conducted.

4 FINDINGS

The responses to the questionnaire survey can be presented in Table 2. Based on Q1, all TE teachers have not integrated any content related to ESD design activities into TE lessons. As a follow-up to Q1, all teachers answered Q9 to Q12.

Table 2. The teachers' answers in the questionnaire survey

Teachers' answers in the questionnaire survey from Q9 to Q12 (Q1:NO)	
Questions	**Consolidated key perspectives based on teachers' responses**
Q9. Why do you not integrate any content related to ESD design activities into TE lessons? What problems did you face?	・Current teaching materials are not enough for developing ESD design activities
	・Teachers have low motivation and incentives to do ESD design activities
	・Students do not have high thinking skills and life experience to solve complex sustainability issues
	・Teachers do not have deep understanding and teaching experience of ESD and design process
Q10. Did you try to solve the problems in Q9? If yes, what are the outcomes?	・Teaching materials should be improved through Internet and related books
	・Assessment methods should be changed, putting the assessment related to ESD into rubric
	・Students' basic knowledge of ESD should be cultivated
	・Teachers' knowledge and skills about ESD and design thinking should be improved
Q11. What are the expected objectives for developing ESD design activities? Or what are the expected student outcomes of these ESD design activities?	・Students' ability to find and solve problems in daily life can be improved
	・Students can link the subject of technology education with their life
	・Students can improve interests, thinking skills and practical ability in solving problems by increasing the difficulty of solving problems
	・Students can solve problems from more different perspective and ways
	・TE lessons can be more engaging
Q12. Is it possible to integrate ESD design activities into TE lessons? If yes, which parts of the current curriculum do you think that can be changed and how to change?	・Teacher training of ESD and design should be strengthened
	・The issues related to ESD is too difficulity for TE students and teachers in junior high schools
	・The TE lesson time is too limited to integrate ESD design activities
	・The motivation of TE teachers for doing ESD design activities in Japan should be improved

There are mainly 3 reasons teachers did not integrate ESD design activities into TE lessons. Firstly, teachers do not have a deep understanding and teaching experience of ESD and the design process. This part of the finding is consistent with previous studies. Secondly, teachers perceived that students do not have high-level thinking skills and life experience to solve complex problems. Thus, teachers are less motivated to implement ESD design activities because they would prefer students to solve concrete problems related to daily life rather than complex ill-defined problems related to sustainability. One of the teachers also reflected that the current teaching materials are insufficient to support ESD design activities.

Regarding the issues mentioned in Q9, teachers did not take any approaches to solve those issues. But the teachers provided some suggestions. Firstly, teacher training should be strengthened to improve teachers' knowledge of ESD and design. Then, the current assessment method of class activities should be changed. For example, summative assessment is more emphasized at the moment. Thus, the assessment rubric should include formative assessment related to ESD. Additionally, improving students' knowledge of sustainable development and design thinking skills is necessary.

The teachers think it is possible to do ESD design activities in the current TE lessons. Most of them believe that the key objective of ESD design activities is to improve students' problem-solving skills and learn to solve problems from different perspectives and ways. Also, some teachers think students can improve their critical thinking skills. In addition, they hope students can be more interested in TE and better link TE with their daily life through ESD design activities.

To further understand teachers' teaching conditions, a field survey was conducted. During the field survey, we can understand that teachers have limited teaching time. Each TE class is 50 minutes, and the total teaching time for 3 years program is 87.5 hours. Due to the limited teaching time, implementing ESD design activities as new content into current TE lessons will increase TE teachers' workload.

5 DISCUSSIONS AND LIMITATIONS

From this case study, the feedback from the TE teachers provided several implications for redeveloping the current TE curriculum to implement ESD design activities. Firstly, it is difficult to integrate ESD into the TE curriculum as new learning content because of the limited teaching time.

The current TE curriculum has four main learning contents: A. Materials and their processing, B. Nurturing living things, C. Energy conversion, and D. Information processing [23]. In most cases, TE teachers teach these contents sequentially. The learning objectives of these contents can be divided into 3 categories: 1) Basic knowledge and skills of technology; 2) Thinking, judging, and expressing about solving real-world problems; 3) Proactive, interactive, and deep learning of promoting sustainable development through technology. Refer to Figure 2.

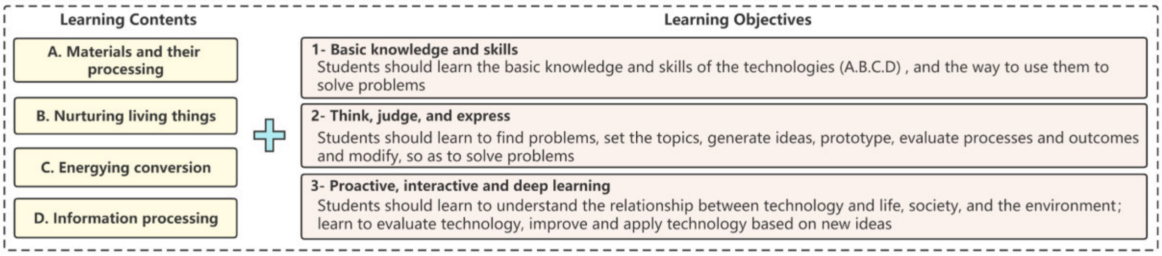

Figure 2. The learning contents and objectives of technology education

As such, instead of teaching the learning contents of TE separately, all the learning contents may be regrouped and integrated into ESD design activities. Complex sustainability issues can be the themes used in ESD design activities. Students can be taught how to use the design thinking process to solve these complex sustainability issues. Through the design thinking process, students can learn to narrow down complex sustainability issues to a specific problem related to their own experience to solve.

To regroup the learning contents and teach the design thinking process, the current TE curriculum may be redesigned through PBL, which means ESD design activities can be structured as design projects based on the PBL approach. A framework for ESD design projects can be proposed. Refer to Figure 3. By redesigning the current TE curriculum, different learning contents of TE can be integrated into a series of ESD design projects. The necessary knowledge and skills will be integrated into projects to help students find design solutions. The design process starts with identifying design problems related to sustainability, idea generation, development of ideas, and testing and evaluating prototypes. The number of design cycles of the design process that can be done will depend on the lesson time teachers have for the projects. Therefore, if the design problem cannot be solved completely after the test and evaluation, teachers can ask students to update the problem and continue the design process. Students can also end the design process with a reflection after the test and evaluation in the first design cycle.

In addition, the curriculum can be designed with a scaffolded approach. Refer to Figure 4. In the scaffolded approach, the projects can be designed by the level of difficulty. In the first year, students can solve problems related to their daily life with a concrete objective. In the second year, projects can broaden the scope and complexity of finding and solving problems. In the third year, students can learn to solve ill-defined problems where they need to narrow down complex problems to a specific problem by themselves. Several learning objectives can be achieved through ESD design activities, and students' design thinking skills will be strengthened in stages.

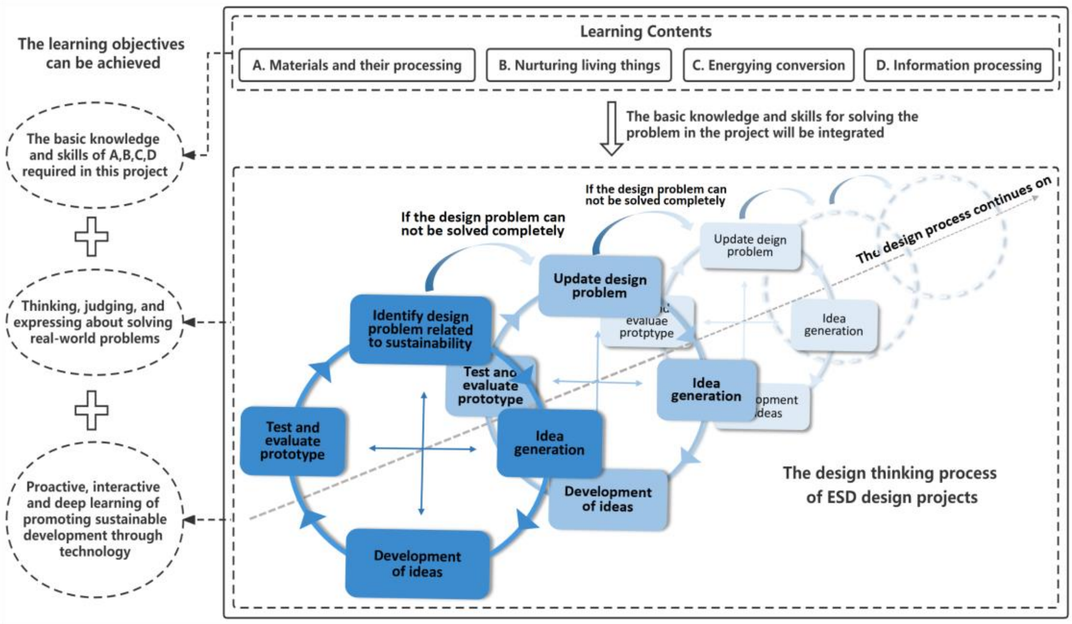

Figure 3. The framework for planning ESD design projects in TE

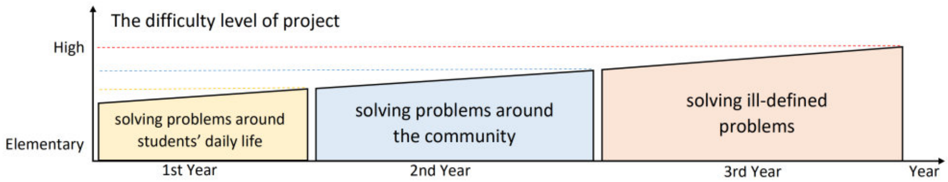

Figure 4. The difficulty level of ESD design projects can be scaffolded in the respective year of study

The framework suggested above mainly regroups and integrates all learning contents into ESD design projects. As such, the learning contents of TE may not increase much in limited teaching time. The teachers' workload may also not increase much.

Although the Japanese national syllabus requires developing ESD design activities in the TE curriculum, most schools did not do it well due to the lack of strategies. The framework for planning ESD design projects suggests in this study addresses part of the needs for the lack of strategies to implement ESD design activities in TE. The current framework (Figure 3 and 4) may bridge the gap between the national policy of developing ESD and school implementation of ESD design activities. But more research in studying best practices is required to find more available strategies.

The limitation of this study is that the feedback comes mainly from four TE teachers in Nara City. As this is just the initial stage of the study, further clarification will be required for future research to determine if most TE teachers in Japanese public junior high schools provide similar perspectives. Besides, the suggestion of this study is just a theoretical concept that has not been implemented in schools. The next step of this study will do a trial to implement this project plan in the actual schools.

6 CONCLUSIONS

The study aims to clarify the TE teachers' challenges in Japanese public junior high schools when implementing ESD design activities. Currently, the main barriers faced by TE teachers to implement ESD design activities are due to a low understanding of ESD and design, low motivation to implement ESD design activities, insufficient teaching materials, and limited teaching time. This study suggested a framework for TE teachers to redesign the current TE curriculum by regrouping and integrating different learning contents of TE into ESD design projects. The framework for planning ESD design projects suggest in this study is only one of the possibilities for implementing ESD design activities into TE. More research is required to study best practices to implement ESD design activities into TE.

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DESIGN AND ENGINEERING IN ACADEMIA: LEARNING FROM PRACTICE

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ABSTRACT
Design is a creative and innovative process that takes advantage of engineering's technical knowledge to develop products, services, and benefits for a consumption-driven society. This article highlights the importance of a coordinated approach between design and engineering education as a driver for innovation. To validate this concept, we analyzed several use cases undertaken at a higher education institution that resulted in the systematization of the adopted methodology. Then, a case study, the RnHealth TECH project, has been used to validate the proposed methodology. This project, aims to design and develop new technologies and products, and create interactive materials to prevent and promote awareness regarding the risk of exposure to indoor radon gas, a radioactive gas that tends to accumulate in indoor environments with a known relation to lung cancer. In this context, design and engineering students are collaborating on the design and development of a set of Internet-of-Things (IoT) devices for Indoor Air Quality (IAQ) management and thus promote awareness-raising. Although engineering methodologies have tasks that overlap with the design process, with a focus on functionalities, they may face technical implementation constraints. Product design, on the other hand, must respond to user requirements, user interface, market needs, and product manufacturing requirements, with a focus on satisfying consumers. These two areas complement each other, resulting in a continuous improvement process of product design, particularly in the innovation process development. This multidisciplinary synergy between students and researchers works both ways, with each functional area contributing to the work according to its specificity and influencing the final product. This approach not only develops students' specific technical knowledge but also provides them with new skills that can be applied to improve their technological literacy.

Keywords: IoT, smart technologies, design, engineering

1 INTRODUCTION
Design is a process that involves creative thinking and innovation to develop new products and services that enhance people's lives and contribute to the society's well-being. To create successful products, designers rely on the technical knowledge and expertise of engineering. The collaboration between design and engineering helps designers understand the functional and technical aspects of their creations, allowing them to develop products and services that are both practical and visually appealing. By providing engineering's technical knowledge, designers ensure that their designs are reliable, safe and meet consumers' needs. As a result, designers must consider not only the functional and technical aspects of their designs, but also their impact on society and the environment.
This article proposes a methodology for integrating engineering practices into Design development for new products creation. The methodology is demonstrated through the implementation of projects within the Master in Integrated Design course at the Polytechnic Institute Viana do Castelo, Portugal. These projects showcase the benefits of interdisciplinary collaboration between design and engineering in product development [1-3]. As a result, the systematization of the adopted methodology has been presented with a case study, the RnHealth TECH project, which has been used to validate the proposed methodology. This RnHealth TECH project, aims to design new products, develop new technologies,

and create interactive materials, to promote awareness regarding the risk of exposure to indoor radon gas, a radioactive gas that tends to accumulate in indoor environments with a known relation to lung cancer. In this context, design and engineering students are collaborating on the design and development of a set of Internet-of-Things (IoT) devices for Indoor Air Quality (IAQ) management and thus promote awareness-raising. Design is a practice-based discipline that emphasizes design development, as well as areas such as design history, theory, and criticism [4]. However, designers often think and work primarily through visual means, making it challenging to articulate their ideas using more traditional forms of knowledge [5]. The use cases introduced in this article demonstrate the value of interdisciplinary collaboration in the creation of new products. The methodology used in the development of these use cases involves stages or cycles that consider the risks inherent in the design process, focusing on problem-solving and the needs of the end-user. This holistic approach emphasizes the importance of integrating engineering considerations into the design process. The results of these projects can be verified in the respective publications, where data and findings are presented in the form of tables.

2 DESIGN AND ENGINEERING IN ACADEMIA

Product and design development teams today require seamless collaboration between designers and engineers who possess multidisciplinary skills [6]. Such integration leads to innovative design and engineering methodologies and new synergies, broadening the scope of service delivery. The focus of product design and development has also evolved, with a greater emphasis on sustainable and socially responsible design that meets user needs, creating opportunities for designers to make a positive impact on global communities while advancing technologies that support sustainable development [7]. To succeed in this new paradigm, designers and engineers must adapt and embrace new responsibilities to ensure the successful realization of products. To be effective, they must possess new skills, including creative design abilities and a user-centered perspective. In recent years, there has been a convergence between design and engineering in academia, characterized by interdisciplinary and integrated approaches [8]. Some educational institutions have transformed the teaching of design and project engineering to encompass human, social, collaborative, and sustainable aspects [9, 10].

In academia, the integration of design and engineering has been a growing trend in recent years. Institutions like Finland's Aalto University, which is defined as a multidisciplinary community focused on engineering sciences, design, art, and economics, have embraced this approach [11]. Similarly, other universities have also started integrating design and engineering into their curricula. These institutions are shaping the future of design and engineering by creating knowledge through multidisciplinary courses that incorporate design concepts and methods throughout the program. For example, at Stanford University in the United States, the Masters of Science in Design program requires candidates to have a background in science or engineering [12]. The curriculum of this program encompasses three key areas: the Design Core, Methods Focus Area, and Domain Focus Area. This approach highlights the importance of cross-disciplinary education in the field of design and engineering. Polytechnic Institute Viana do Castelo (IPVC), Portugal, was established in 1985 in response to the demands of the labor market in the Alto-Minho region of northern Portugal. This institution serves as both a higher-level training center and a scientific and technological training center that trains qualified professionals in technology and management and the relevant sciences and techniques. During the academic year 2021/2022, 13 vacancies were opened for undergraduate students and 8 for master's students, with a total of 1900 students enrolled in degree courses and 315 students enrolled in master's courses. Of the courses offered at IPVC, eight belong to the field of engineering (including food engineering, civil and environmental engineering, graphics and multimedia computing, networks and computer systems, information technology, mechanics, and mechatronics), two to design courses (product and environment design), and the remaining courses belong to the areas of management and tourism. Although IPVC is recognized for its expertise in engineering, the design field is also growing, with around 60 students enrolled in the product design course and 40 in the environment design course in 2021/2022, and approximately 30 students enrolling annually in the master's course.

The increasing competition in consumer markets and growing recognition of the importance of design in the market have reinforced the belief that design success can only be achieved through the integration of both engineering and design skills [13]. The division between these distinct disciplines is eroding, particularly in the realm of product design and development, where designers and engineers work together to expand their range of services [14]. The convergence of design and engineering brings together the human aspects and aesthetic-formal elements of design while emphasizing the technical skills of engineering and the human skills of design [15]. This integration gives rise to the concept of "creative engineering" or "creative engineering design," which envisions the "redesign of the engineering mind" through a creative process [16].

Despite the differing curricula between the fields of design and engineering, IPVC fosters collaboration between these two areas within the Master of Integrated Design students and research and development (R&D) activities carried out at existing reseach units in IPVC. These opportunities allow students to apply their knowledge through project-based learning, which is a more effective means of assessment compared to traditional problem-solving activities that do not result in a tangible outcome. Project-based learning is a crucial aspect of design education, as it instills the tools and techniques of design practice early in the curriculum and provides ample opportunities for skill, knowledge, and confidence development. Table 1 presents some examples of product design achieved through interdisciplinary pedagogy that integrates engineering science and design. To facilitate the convergence of these two distinct worlds - technical and creative - the application of tools and techniques to support the design process was emphasized from the outset, particularly those that promote the principles of sustainability in the current discourse on the future of humanity.

Table 1. Projects where an interdisciplinary pedagogy was used, integrating engineering and design

Project name and date	**Involved areas**	**Publications**
Design as an Enhancer in Stimulating Individuals with Dementia (2016)	- Product Design; - Computer Graphics and Multimedia Engineering; - Psychology.	- Master thesis project in Integrated Design
UX design in the mobile application of accessible routes to the city center of Viana do Castelo (2019)	- Communication design; - User Experience Design; - Computer Science and engineering.	- Master thesis project in Integrated Design. Published Articles: [17]
Design and Sustainability at Academia: the practical case of reducing the consumption of plastic bottles in the IPVC community (2021)	- Product Design and Communication; - Network and Computer Systems Engineering.	- Master's Project in Integrated Design; - Refill_H2O, an EEA Grants Portugal Environmental Project. Published Articles: [18-20]
Design applied to the development of IoT products for intelligent environments (ongoing)	- Product Design and Communication; - Network and Computer Systems Engineering.	- Master's Project in Integrated Design; - Part of RnHealth Project

The projects presented in Table 1 demonstrate the belief that project-based learning is a productive, collaborative and highly effective method for educating designers and engineers in the field of product design and development. As such, new innovations have emerged, such as Co-Creation and Design Thinking [21], which serve as methodologies for addressing the uncertainty inherent in the conceptual phase of any innovation project. These approaches have been widely recognized and documented in the literature [22, 23].

3 FOSTERING DESIGN AND ENGINNERING: A METHODOLOGY

We have previously analyzed several use cases undertaken at IPVC that resulted in the systematization of the adopted methodology. In this section, a case study, the RnHealth TECH project, will be used as an use case for the proposed methodology. The RnHealth TECH project, an initiative of IPVC, aims to prevent and promote health through innovative technologies by examining the presence of radon gas in buildings and evaluating its potential impact on pulmonary health in Alto Minho, Northern Portugal. To achieve this, a project was initiated to develop mobile devices for air monitoring. This resulted in the creation of four devices, including a radon gas analysis sensor, sensors for monitoring CO_2, temperature, relative humidity, and VOCs gases, an infrared camera for analyzing the number of people in a room, and a fan and a differential pressure sensor for mitigating negative air quality factors.

A multidisciplinary team of students and researchers from areas such as Civil Engineering, Biomedical, Electronics, Telecommunications and Informatics, and Arts and Design, collaborated to design and develop a new IoT-based product for IAQ management. The composition of the team was governed by

a multidisciplinarity of areas, as well as students aged between 22-28 years who are finishing their courses and have shown interest in participating in the project. The team was led by three senior researchers and included a student from the Master's in Integrated Design program and two Bachelor students of Networks and Computer Systems Engineering. In the initial phase, the team employed the Design Thinking approach, which utilizes design tools and methods to explore solutions and ideas and validate them through fast and iterative prototyping. This human-centered practice is recognized for its integrative thinking, exploration, and visualization.
The study is based on data, information, knowledge, and research to acquire design knowledge applied to product design. The analysis is based on a cross-methodology, as illustrated in Figure 1.

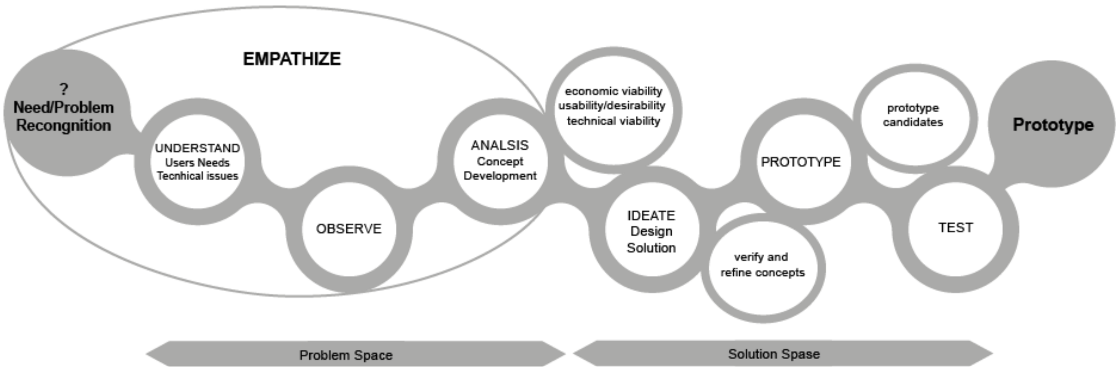

Figure 1. (adapted fromRattcliffe [24])

According to Rattcliffe [24], the Design Thinking process can be separated into two clear "spaces": the problem and solution spaces. From a cognitive point of view, it is a combined divergent and convergent process, where a set of alternatives is created, and only then are choices made based on the different options [21]. The problem spaces is considered an empathy phase. Empathy is the centerpiece of a human-centered design wich is a process of creating things deeply based on general natural characteristics and peculiarities of human psychology and perception. Empathize mode is the work done to understand people within the context of your design challenge. It is their effort to understand the way they do things and why, their physical and emotional needs, how they think about the world, and what is meaningful to them.
Observing users, behaviours, relevant contexts, and interviews are key aspects of this first phase. Perceiving people makes it possible to capture physical manifestations of their experiences - what they do and speak. This will allow you to infer the intangible meaning of these experiences to unlock insights. These insights guide you to create innovative solutions. The best solutions result from the best insights into human behavior. Direct involvement with people reveals a tremendous amount about the way they think and the values they defend [24]. The solution scape is the oriented phase, starting with Ideate, in which the team will delve into the existing problem and solutions, looking to understand the "big picture" and needs. Iteration is critical to good design. It iterates by cycling through the process several times or iterating within a step - for example, creating multiple prototypes or trying variations of brainstorming topics with multiple groups. In general, as you make multiple cycles through the design process, its scope narrows, and you move from working on the broad concept to subtle details, but the process still supports this development. For simplicity, the process is articulated here as a linear progression, but design challenges can be met using design modes in various orders. In addition, there are an unlimited number of design frameworks to work with.The phase evolves with a clear exposition and specific problem to be addressed within the scope of the challenge. This is followed by prototype and testing, where the team creates rapid, close prototypes of solutions to the needs they've discovered and then tests them with users to get feedback. Testing is another opportunity to understand the user, but unlike the initial empathy mode, now have more problem-framing and creating prototypes to test.
Several proposals are presented, a final solution is chosen, and, in the test phase, the selected solution is developed, including a working prototype. Thus, a learning experience based on challenges is proposed, in which learning is carried out through the identification, analysis and design of a solution to a socio-

technical problem [25]. The search for new ideas and innovative solutions to complex problems is inherently uncertain and has fewer specific results than improving existing solutions.

4 FINAL CONSIDERATIONS

In today's world, transdisciplinarity is of utmost importance to bring together competencies that are disseminated through disciplines that act alone. This research plays an important role to promote the interplay between Product Design, Electronics, and Materials Science to create insightful deliverables that may lead to the development of innovative product solutions. The Internet of Things (IoT) involves the integration of everyday objects with the vast network of data and information available on the internet, enabling their operation and functionality through a computer, smartphone, or other internet-connected devices. This world opens up new avenues for human-object and object-object interactions, as well as real-time monitoring of physical changes. Therefore, the methodology plays a crucial role in the entire project monitoring process, contributing to the identification and resolution of research questions that may arise during the design process and enriching the conclusions of the research.
The proposed methodology is, promoting not only the knowledge transfer and teaching of the Design process but also facilitating teamwork in the development of effective methodologies. Design creation prioritizes stages that focus on the user and their needs, as well as the final construction of the project, while engineers, with a more practical and results-oriented background, aim to solve problems, optimize results and efficiency, and construct prototypes with a focus on the planned design, adopting a different approach within the various phases. The investment in initial research is immediately advantageous as it defines the systematic framework for a project.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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HAND DISABILITIES STUDY AS FRAMEWORK FOR FUTURE DISABLED DESIGN - COOKING TO INCREASE SELF-ESTEEM: EVIDENCE FROM HONG KONG

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ABSTRACT
People with hand disabilities are influenced greatly in various daily activities, such as dressing alone and engaging in cooking tasks. Being limited by the use of only one hand may also have an impact on their self-esteem due to the biopsychosocial approach and social exclusion, despite their ability to manage many of their daily tasks independently. Thus, cooking, which could be a solution for them to face the challenge and support their family by themselves, can serve as an alternative platform for proposing design utensils that support them in developing their self-esteem. Research shows that carrying heavy utensils and processing ingredients systematically with one hand would be a significant challenge in Asian cooking. Therefore, an evaluation of the benefits and drawbacks of pot and chopping board designs could be conducted, along with recommendations for improving the design of such tools for the design educational purpose. Since research is still developing, the design criteria for the cooking utensil which aims to smoothen the cooking process with one hand would be conducted toassist target users in building their self-esteem through cooking.

Keywords: Single hand, disability, cooking, family, challenge, Asian

1 INTRODUCTION OF ONE-HAND DISABILITY

According to the HKSAR Rehabilitation Programme, any person, who has skeletal, musculoskeletal orneurological disability impairment, and mainly impaired motor function, causing the restriction of daily activities, would be defined as a physical disabled person [1]. This indicates whether those invalided persons are long-term or short-term, such as hemiplegia stroke patients and the casualty with fracture, once the mobility and dexterity of their hand would largely affect their daily life would be one-hand disabled. Although Hong Kong's total population of upper limbs disabilities is only 0.9% [2], people in the world who suffered from the single hand disabled challenge are still high and may increase potentially. In 2018, 450 thousand single hand disabilities already faced hand or arm mobility problems in China [3]. Almomani et al. also points out that young people also have a higher risk to have a range of potential risk factors of upper limb disability and pain since they have approached plenty of electrical devices with inadequate gestures over a long period of time [4].

2 MENTAL CHALLENGE OF ONE-HAND DISABILITY

Hong Kong Federation of Handicapped Youth, conducted an interview researching on physical disability, points out that body-disabled people not only have physiological needs, but also mental and social needs, otherwise biopsychosocial approach and social exclusion would be the barrier to one-hand disability [5]. The biopsychosocial approach refers to the model that consists of both disease and illness, which are based on "the disruption of specific body structures or organ systems" (p.582) and "subjective experience or self-attribution" (p.582) with interpersonal respectively [6]. This indicates that there is a correlation between physical capabilities and mental well-being based on ICF [7] and that reduced performance resulting from hand impairment may affect their self-esteem negatively, compared to those who are able-bodied. Feelings of "anxiety" and "loneliness" are sometimes experienced by physical impairment because of challenges in performing certain activities and sharing their emotions with others [5].

In the social aspect, hand impairments may also experience a mental barrier because of different appearances or lower capabilities compared to others. Larocca et al. explain that the reason some disabilities have a low rate of joining physical activities is the reinforcement of physical limitations from environmental factors [8]. Therefore, their motivation and positive attitude toward the community may decrease, leading to a reduction in their participation rate in social activities. In Hong Kong, the employment rate of physical disability among the population of all disabled persons is only 4.4% compared to the attention deficit hyperactivity disorder (ADHD) persons, that has an employment rate of 31.5%, which is nearly 8 times the difference [9]. This reflects that the physically disabled, like one-hand persons, may have a lower connection to the community and the risk of social exclusion to them possibly higher which may impact their mental well-being negatively because mental illness, like anxiety, could relate to lack of ability to perform an activity because of various scale of impairment [10].

3 COOKING IMPACT ON MENTAL WELL-BEING

Cooking, which requires extensive use of both hands, could be considered a highly complex skill for hand disability. Mastering such skills could build up their self-esteem and provide a significant sense of accomplishment for them. Gainforth et al. also support that higher independence and exercise status rates for physical disability could bring out a positive outcome to themselves, as these actions could promote a positive perception and value to themselves [11]. From a social perspective, hand impairment, who responded to cooking household duty, could provide independent support for those they care for, presenting their ability to show love and care. Therefore, adequate performance of meals, particularly dinner, could be important to a hand impairment to demonstrate their value to their love because dinner preparation, in which the chance of family sitting together is higher and is a platform for establishing and maintaining a family relationship, has a richer food preparation in Chinese food culture [12]. Additionally, structured cooking has the potential to bring a positive psychosocial outcome by improving executive functioning through multitasking and has been successfully practised as various sets of mental therapy to allay some mental illnesses [13]. Hand-disabled persons could cultivate positive mental attitudes by engaging in a complete series of cooking activities. Bryant and McKay also conducted research on the usability of the cooking process with occupational therapists and point out that cooking in the kitchen could be occupational therapy since cooking is a creature and social model, which both factors are also practised for disabilities [14].

4 METHODS

Since cooking is an adequate platform for hand disability to build up self-esteem, research on cooking challenges with one hand were conducted. This aims to identify the design preference of cooking utensils for hand impairment. The design preference shall be defined as the improvement and direction for future disabled cooking design, including the cooking problem with one hand and the potential design solution, which would be elaborated in study 4.1 and 4.2 respectively.

4.1 Case study for cooking challenge with one hand

To gain insight on the cooking experience with a single hand, a study was conducted with the participation of two people, both of whom has cooking experience, and are disabled in one hand. Both were male between the age of 40 and 65 and their interviews were conducted through face-to-face and phone. As the number of participants was limited, additional cooking testing in Table 1 would be necessary to prove the finding (Figure 1).

In this study, both participants highlighted that the time consumption was a major issue, as they were only able to apply one hand to process ingredients during the multi-tasking cooking activities. They needed to learn and adapt to overcome mobility and dexterity issues in cooking by using specific tools. One of the participants stated that "If people need to start dinner at 7: 00 pm, normal people may need around 1 hour while I need to start at 4:00 pm". This indicates that certain daily events, such as cooking, are less efficient for them compared to those without. In fact, suitable tools could enhance theeffectiveness of cooking activities. For instance, in Table 1, the result of the slicing test by using a knife with one hand spends 54 seconds, which is more than 3 times the time taken when using a knife to slice with two hands, this shows that time consumption may occur for hand impairment when facing dexterity and mobility problems. On the other hand, when using scissors, time was largely reduced to 19 seconds. This demonstrates that some skills and tools needed to be learned and adapted to improve efficiency.

Table 1. Physical testing of slicing food

Process	Knife	Scissor
Average time spent with one hand	54 sec	19 sec
Average time spent with both hands	18 sec	6 sec

Strength and mobility were also major issues for both participants during cooking, as pots and pans, are often bulky and heavy, and are difficult to carry with one hand. One of them stated that he could only use a thick rope as a tool to carry the pot carefully. Canning et al also notice that strength and dexterity are major issues for physical disability due to the loss of muscle activity [15]. During the physical testing (Figure 2), the bowl was necessary when adding water to prepare noodles because the pot would be relatively heavy when adding water directly from the tap with the use of one hand to support it. As a result, a smaller bowl would usually be used to replace the pot and repeat the water-transferring process several times which shows that strength and mobility could be limited whenthey could only use one hand for cooking.

Figure 1. Noddle cooking process

Figure 2. Transferring water for cooking

This study has shown that processing ingredients and carrying cookware requires extra tools and strength to slice food as well as supporting the weight of tools, these were usually the major challenges face for the one-hand disability. To provide an adequate cooking experience for them, it is important to define the future disabled design framework that addresses the challenge faced in designing cook utensils. Further study is needed to identify the specific utensils design challenge that should be overcome to create a more suitable design for one hand impairment.

4.2 Case study for soup cooking with one hand

Soup, which is a portion of comfort food, is an important part of Hong Kong food culture. In this study, soup cooking was considered as a specific case in this research to provide a clear design direction for designing a hand-disabled cooking utensil. In 2018, the frequency of boiling soup in Hong Kong is around 2.5 times each week which is around 900 thousand soups that have been prepared a day in total [16]. Plus, soup cooking process involves transferring and slicing ingredients, which could be challenging for hand impairment users due to the reduction of strength and support. Therefore, both pot and chopping board designs, that could assist them to cook soup independently for dinner, were addressed to develop for them in the following.

4.2.1 Pot carrying for soup cooking

Plenty of existing pots have been designed with two side handles for two-handed carrying and some cover designs of the pot are created without a hole, leading it difficult for people with hand disabilities to support the pot with a single hand. Although some pots could be locked with the cover, this mainly aims at pouring activities with both hands. To address the challenge of carrying heavy cookware process with one hand, the pot cover handle with a locking system has the potential to be developed.

Figure 3. Existing pot study

In the handling study, two types of handles for the pot were designed and tested, one held by the wrist and another by the forearm. During the testing, the handle designed to be held by the forearm has higher strength for carrying a pot due to the muscle in the forearm being stronger than those in the wrist area (Figure 4). This design could also hold the pot more stable when preparing water for soup boiling and shorten the time for transferring water by using a bowl with one hand. On the other hand, the handle designed to be held by the wrist has higher flexibility for one hand to move due to the cluster of carpal bone in the wrist being small and oval in shape, allowing for greater flexibility in various gestures and locations (Figure 5). This design not only allowed the user to depend on the weight of the pot to adjust the orientation of the wrist for transferring purposes but could also hold up the handle at various heights of the location, such as the top or the side. Comparatively, the handle designed for carrying by the wrist is better than by the forearm since it is more flexible to use. Even though the handle designed for carrying by the forearm allows users to carry heavy containers with less strength, its circular tunnel form could only provide one way for the user to carry, which highly reduces its user-friendliness by limiting the flexibility of moving their hand while carrying.

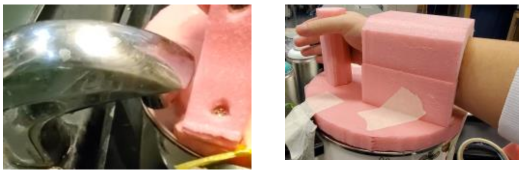

Figure 4. Design for one hand forearm holding

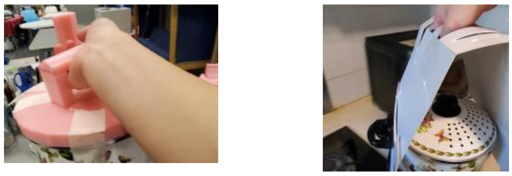

Figure 5. Wrist holding orientation

To improve the process of carrying the pot, two designs were tested, which were an accessory and a redesign of a pot lid. Although the accessory was able to adjust to hold various dimensions of pots, it requires the use of rope that needs to be controlled and surrounded by one hand, which hand impairment could take time to adapt to (Figure 6). Therefore, the redesign of a pot lid with a new handle design was a development of the accessory, inspired by the form of the gripping of common iron handles. It includes features such as a waving form handle for fitting the natural contours of the hand as well as providing comfortable gripping (Figure 7). Waved design of the handle could also distribute the weight and pressure more evenly across the hand, reducing a feeling of tiredness when carrying. Groove is designed from the top of the handle for easy application of forces to enhance the ergonomics of the design.

Figure 6. Accessory testing

Figure 7. Handle testing for pot design

4.2.2 Ingredients processing for soup cooking

Chopping is another challenge for hand-disabled people because it requires both fixing and cutting forces at the same time, which could only be applied one at a time. While many chopping boards have been designed for upper limbs disability, they could be dangerous by involving the use of needles (Figure 8). To find a better solution for the chopping process with one hand, various forms of grooves on the chopping board have been tested by chopping with various types of food (Figures 9 and 10). In the chopping study, short teeth are still needed for the groove to grip different sizes of ingredients but the length of the sharp area is reduced due to the barrier from the groove. This could help avoid the risk of injury when placing ingredients with a single hand, compared to using a chopping board with needles.

Figure 8. Existing one-hand chopping board [17]

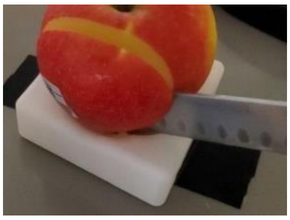

Figure 9. Cutting hard food, apple, testing

Figure 10. Cutting soft food, tomato, testing

To enable a hand-disabled person to express their support through cooking, further development of the chopping board has been identified, including the flexibility for slicing and transferring ingredients systematically. The half-sphere and cylinder groove design, acting as a barrier, could fix the position of various forms of ingredients, such as apples and carrots, when chopping. Testing has also shown that the orientation of chopping ingredients with the left and right hand are different, so a rotatable chopping board has been designed to suit both left or right hand impairment. In addition, the rotating feature of the working zone could increase the mobility for transferring ingredients. This allows them to directly transfer the food from the chopping board to the bowl nearby and carry it to the pot, reducing the repetition of the cooking process. Considering other ingredients processing methods, suchas mixing ingredients, the chopping board design could be suggested by fixing the bowl on the board to prevent it from moving (Figure 12).

Figure 11. Design for chopping with one hand

Figure 12. Chopping board Prototype for one hand

4.2.3 Discussion

Since both pot and chopping designs for hand-disabled persons have been developed and tested, the design preference for disabled design would be identified as follow:

Pot handle design

1. Designing a wrist handle to improve the use of flexibility.
2. A handle with a waveform for carrying heavy cookware ergonomically.
3. Design with a groove where the thumb rests to generate force easily.

Chopping board design

1. Half sphere and cylinder groove with shortened teeth to grip ingredients safely.
2. Left and right-hand orientation designs for chopping should be considered.
3. Groove placement for bowls to apply more force for other cooking activities.

Overall, both redesigns of the handle and chopping board could be an example to show alternative design perspectives to cope with the cooking challenge of carrying heavy cookware and processing ingredients with one hand ergonomically and systematically.

5 CONCLUSIONS

Due to physical limitations, people with hand disabilities often face challenges related to the biopsychological approach and social exclusion, could impact their mental well-being negatively. To assist them in building positive values and self-esteem, cooking activities, particularly soup cooking, could be an alternative way to express support for their love independently and gain a sense of accomplishment because cooking is not only a multi-tasking complex housework duty but also could be a professional technique and create the opportunity for people gathering. Soup cooking were addressed in this research, as it is the major cooking element in Hong Kong and involves two major one-hand cooking challenge activities, carrying heavy cookware and processing ingredients. To provide a clear framework for designing cooking utensils for hand impairment, a pot handle design and the form of a chopping board have been designed as an example for testing. Since both disabled cooking utensils of the pot and chopping board are conceptual designs to identify the design framework for hand impairment, the general perspective of those works would be analysed further in order to create a better cooking platform for them as well as enhancing their self-esteem.

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ENHANCE CULTURAL COMPETENCE AND CREATIVE ABILITIES THROUGH INNOVATION EDUCATION OF TRADITIONAL TECHNIQUES

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ABSTRACT
Creative education is a process for training students' creativity and problem-solving skills, it helps them enhance their personal development leading to conduce to their future careers and quality of life. The creativity and innovation industries have become the future trend in Hong Kong's development in order to improve worldwide competitiveness. Alison indicated that cultural differences start to emerge at a young age and those leads to all sorts of subtle differences in the way we think and acts. In which, secondary school students are much easier targeted to integrate into difference cultures. According to Hong Kong Intangible Culture Heritage Office, bamboo crafts provide citizens with a sense of identity and continuity. Bamboo craft is one of the famous traditional techniques in Hong Kong's culture, involved in different application in our daily life such as cookware, containers and building techniques. Besides, there are items that occasionally appear in seasonal festivals or funerals such as bamboo theatres, offerings and lion-dance. The knowledge and techniques taught through this project contains enlightening and cultural-specific elements, contributing to the development of a proper "maker's mentality" in future generations, whilst preserving traditional Hong Kong Craftsmanship in an engaging and meaningful manner. Possible opportunities are identified for educating bamboo crafts for future generations in order to cultivate students' creativity, critical thinking and problem-solving skills. The purpose of this study is to develop techniques for using traditional craft learning and teaching materials to improve students' cultural and creative abilities and to inherit traditional Hong Kong handicrafts.

Keywords: Creative education, traditional crafts, bamboo crafts, cultural education

1 INTRODUCTION
Students lack innovative education in Hong Kong's examination-oriented education system, which limits the students that cultivate their creativity, critical thinking and problem-solving skills. The paper aims to discuss the potential for using traditional crafts to develop creativity and problem-solving skills in students by different methods. In addition, enhancing cultural competence and creative abilities through innovative education of traditional techniques can be a valuable approach to preserving and celebrating cultural heritage while promoting innovation and creativity. To achieve this, combining traditional and modern techniques is an approach that could be used, where traditional techniques are taught using innovative and interactive methods.

2 BACKGROUNDS

2.1 Bamboo crafts in Hong Kong
Bamboo craft is a highly regarded traditional handicraft in Hong Kong, which has found versatile applications in various fields, including daily consumables, building structures and festival items, owing to its adaptability and flexibility (Figure 1). It also demonstrated the cultural significance and the building techniques which only appeared in Hong Kong. Therefore, it is a valuable traditional technique to incorporate into creative learning that educates students on hands-on skills and humanities of Hong Kong. The use of bamboo craft learning and teaching materials to improve students' cultural and creative abilities would be a promising approach to enhancing the quality of education in Hong Kong. By

integrating elements of Hong Kong bamboo crafts' culture, history, and traditions, students can develop a sense of identity and continuity, which can contribute to their personal and academic growth.

Figure 1. Bamboo crafts in Hong Kong

The application of bamboo crafts as a means of developing students' creativity is particularly promising given the cultural and historical significance of this craft in Hong Kong. By teaching students, the maker's mind and the design process behind bamboo crafts, they could gain valuable insights into problem-solving and critical thinking skills. Moreover, the preservation of traditional crafts like bamboo weaving is an essential component of Hong Kong's cultural heritage, and educating students about these crafts can help ensure their continuation into future generations.

Furthermore, incorporating traditional crafts into the curriculum also provides students with a more well-rounded education that emphasises the importance of cultural diversity and understanding. As Hong Kong continues to be developed as a hub of creativity and innovation, it is critical that students equip the necessary skills to succeed in these industries [2]. In addition, by utilising traditional crafts as a means of developing students' creativity, critical thinking, and problem-solving skills, Hong Kong can ensure its continued success and global competitiveness.

Given the ubiquitous presence of bamboo in various aspects of daily life in Hong Kong, such as building repairs and seasonal festivals, the adoption of bamboo craft as a traditional technique for education is highly feasible. This craft technique offers a diverse range of applications, including the construction of bamboo theatres for festivals such as Tin Hou's birthday, lion dances, and lantern festivals. Consequently, bamboo craft can facilitate varied learning outcomes for students, contributing to their personal and academic growth. As a completely handmade craft, bamboo technique presents a valuable opportunity to integrate it into design. By incorporating this traditional technique into design, designers can create unique and culturally significant products that preserve Hong Kong's heritage while also promoting its creative and artistic potential.

2.2 Importance of inherit traditional Hong Kong handicrafts

Traditional crafts are defined as those items in our ‘everyday life, which means a personal experience only occasionally in one year or in one's whole life such as weddings, seasonal festivals or funerals, that is slowly being less known and abandoned by the public [3]. Due to the rapid development of society, some knowledge, things or skills of crafts are gradually being disqualified by the public because of their limited functions or developments. Most of the crafts are being replaced by machines for mass production to achieve more economic income. Besides, after the transformation of the society in the 1980s, the production of traditional Hong Kong handicrafts was gradually relocated to the mainland (Hong Kong Memory). Therefore, leading the younger generation to lack the cognition of Hong Kong’s iconic crafts, they are less concerned about the loss of intangible properties and lack awareness of preserving them.

However, passing down craftsmanship is equivalent to passing down knowledge, which forms the essence of education. The application of traditional handicrafts in people's daily lives demonstrates how knowledge and skills can be used as effective problem-solving methods for various purposes. Besides, the know-how provides enlightening and culturally identified elements and knowledge to the future generation such as notable Hong Kong style design and the maker’s mind, that contribute to their personal development and lead to preservation of the Hong Kong traditional crafts. Hence, significant potentials and possible opportunities are identified by applying traditional Hong Kong handicrafts in creative education and are taught by combining traditional and modern techniques.

2.3 Creative education and cultural education

Education plays an indispensable role in human life, which people used to achieve knowledge and understand a variety of subjects to be applied in daily life [5]. Nowadays, people easily obtain diverse subjects on different platforms such as TV, the Internet, and books. Those understandings possess human behaviours, habits, and arts in different places, which allow individuals to equip themselves more to develop the way they think, reason and act. When people apply arts and cultural activities intentionally to guide the development of understanding, knowledge, and skills, it could be defined as creative education. However, the way of life, customs and beliefs of a particular country or group are defined as the culture that people start to learn in their daily life during their childhood. After that, when people invent or create, most of the inspiration comes from the culture. The more diverse knowledge people acquire, the greater number of solutions they can generate. By the view of this, a more effective creative education system should be established by a comprehensive cultural education.

2.4 Creative education and innovation education in Hong Kong

In Hong Kong, there is a lack of students who choose subjects related to creative learning. According to the charts (Big Exam,2022), only 3448 students entered in Visual Arts at Hong Kong Diploma of Secondary Education (HKDSE), and 170 students entered in Music at HKDSE. With the small number of students, the difficulties of getting greater results in examinations are increased because of the unequalled marking scheme of HKDSE, according to the Hong Kong Examinations and Assessment Authority, students' scores are free to vary in line with fluctuations in overall candidate performance. The lower the number of people who study this subject, the lower opportunities for them to get the highest marks. Therefore, students lost their interest in studying creative learning due to the intensely competitive environment.

In recent years, STEM education has become popular in primary and secondary education in Hong Kong. It is an approach to learning and development that integrates the areas of science, technology, engineering, and mathematics. Although the system enhances the efficiency of students to learn hard skills, and techniques using machines or high techs, there are still some limitations that regulate students to develop their abilities in soft skills such as critical thinking, communication skills and creative thinking. Students who are interested in cultures, music or arts are being regulated by this system. Therefore, some of the stakeholders designed a new education system called STEAM, which opens the door of STEM to the arts aids in the process of turning critical thinking into critical making. During the study, students could have more opportunities to apply the concepts learned in STEM but perform their ideas in the form of arts or designs. As a result, the system helps students understand complex knowledge more figuratively and efficiently. However, adding more cultural elements to STEAM education could help students explore their creativity in different cultures because of the diverse humanities. Therefore, there is a possible potential that combines traditional Hong Kong handicrafts and modern techniques to enhance students' hard skills and soft skills.

3 METHOD

Based on the preliminary research, bamboo crafts could be achieved in the creative education system design and education tools design. To further understand the necessary process of the education system and functions of the educational tools to be most effective for creative education, primary research such as surveys and interviews were conducted via Google Forms and interviews. The surveys aim to collect data about the understanding of creative education and traditional crafts of the public. It is given that they will be the targeted product initiators, i.e., there are the main groups who experience cultural and creative education. Questions from different categories, such as the expectation of them learning in creative education and cultural education, the cognition of bamboo crafts, the methods for creative learning, cultural learning and traditional handicrafts etc., were made into the short answers, checkboxes, linear scales and multiple-choice questions for easier and specified responses.

Five interviews were conducted, with ages ranging from 21 to 60, with two students who studied creative learning in Taiwan, Mainland and Hong Kong, 1 student who studied creative education and internship as a music teacher at a secondary school in Hong Kong and 2 experienced teachers who taught creative learning in Hong Kong. The interviews focus on the experience of study in creative learning and educating creative learning. Students are included in the interview part since they have learned creative learning in different places. Potential design opportunities could be found due to the comparison between different education systems in different countries. The interview questions are more flexible compared to the survey since they allow the users to express their ideas and opinions more clearly, which can stimulate ideas which were not thought of.

4 RESULTS

Over a period of two weeks, there were a total of 46 survey participants (Figure 2). A majority of respondents (above 70%) did not have a clear understanding of creative education and cultural education. The lack of educational resources (textbooks, teaching tools, etc.), study opportunities and teacher resources are the main factors that they think Hong Kong does not have excellent education systems in creative learning and cultural learning (above 50%). Besides, most of them agreed that creative education and cultural education would affect the way they think, reason or act. Statistics about the needs for creative learning and cultural learning were collected from 5 interviews and 46 surveys. The results show that most respondents find a lack of teaching resources and study opportunities in cultural learning and creative learning, reducing the chances of learning humanities and training their soft skills such as problem-solving skills and critical thinking, in which most of them find bamboo crafts a good direction to combine traditional and modern techniques in the creative learning system.

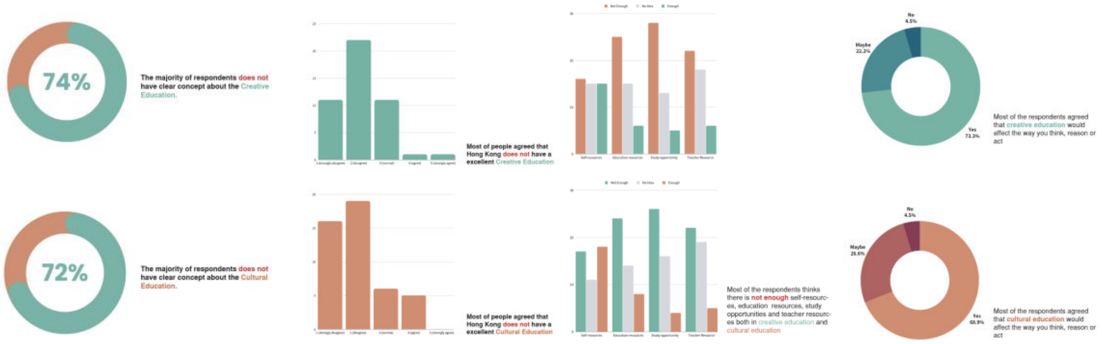

Figure 2. The results of surveys

5 RELATED PRODUCT MARKETING ANALYSIS

According to a scholarly article, contemporary urban society has demonstrated a demand for crafts-based skills and knowledge, leading to a market for such products. In response to this trend, toy manufacturers have developed craft kits for children that have gained popularity among parents due to their ability to replace electronic devices and engage children in playful skill-building activities. These kits have proven to be effective in satisfying children's entertainment needs while simultaneously developing their crafts-based skills. The art-and-crafts toy segment experienced a significant increase in sales in the toy industry from 2013 to 2014, becoming the second-fastest-growing type of toy. Despite the growth of the toy industry, this type of toy continues to occupy a significant share of the market. Notable companies such as LEGOs and Piececool have incorporated their knowledge of architecture and cultural elements into their products, serving as examples of how the toy industry can incorporate knowledge into their products [1].

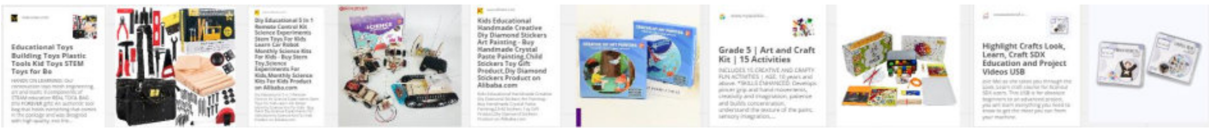

Figure 3. Existing STEM education kits

The limitations of current STEM education products are evident in their design, which primarily focuses on hard skills with less consideration for aesthetics (Figure 3). This approach restricts users from fully utilising their knowledge gained from STEM education to realise their own creative ideas. Similarly, existing craft education products demonstrate limitations in providing users with comprehensive learning opportunities as they lack guidelines on techniques and their associated historical context. Consequently, users are unable to develop a deeper understanding of the creative and cultural aspects of their learning. To address these limitations, there is potential to incorporate innovative techniques such as virtual reality or augmented reality in the design of educational products. These technologies can provide users with immersive and interactive experiences that enable them to explore and understand the historical and cultural significance of various techniques. Additionally, virtual and augmented reality can facilitate a more comprehensive and dynamic learning experience, allowing users to experiment and create within a simulated environment.

6 CONCEPT DESIGN DEVELOPMENT

6.1 Education system design

The design of the educational system and tools seeks to promote creative learning by blending traditional bamboo crafts skills with innovative techniques. Moreover, culturally identified elements and knowledge would be integrated into the educational materials, which help users improve their experiences of generic skills learning and the application of know-how. The design of an educational product that uses bamboo crafts for creative learning is based on existing STEM education tools and follows the SCAMPER guidelines [4].

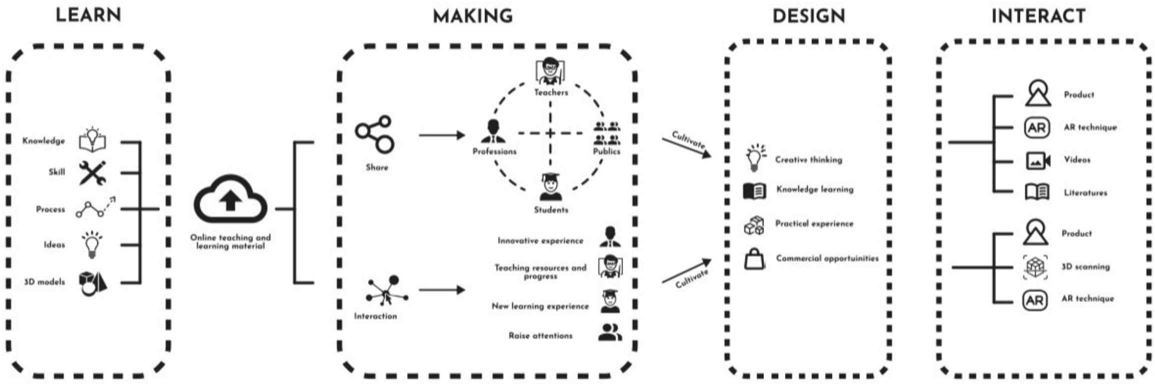

Figure 4. Education system planning

The product takes the remote-controlled car as a model for designing STEM education tools that help users to learn traditional bamboo crafts techniques and modern technology simultaneously. Figure 4 illustrates that the education system design which consider the learning process of students and assisted with the innovative technology in order to enhance the efficiency of learning. Additionally, the product includes tools to guide users in completing the remote-controlled car and encourages them to use their creativity to design its structure (Figure 5).

Figure 5. Prototype process

The education system incorporates hands-on learning experiences that help students understand and appreciate the techniques and materials used in traditional crafts. Besides, the integration of technology, such as virtual reality and augmented reality, can provide interactive learning experiences that allow learners to explore traditional techniques in innovative ways. In addition, bamboo crafts culture is inclusive and diverse, which can help students understand and appreciate the cultural significance of traditional techniques, while also promoting intercultural understanding and respect. As there are designs of the education tools, it encourages students to apply their creativity of traditional techniques which can promote the development of new and innovative designs that reflect the cultural heritage of the techniques. Finally, the design can not only promote the preservation and celebration of cultural heritage but can also foster creativity and innovation in the application of these techniques. The continual development in the design process is to create a 3D-printed, size-adjustable base for the remote-control car (Figure 6). The bamboo base is too thin to support the weight of all the components, so an adjustable base is needed. Additionally, an adjustable base will enable users to design the car with more flexibility and encourage creativity without limitations. However, an improved exterior design could also help to attract a broader customer base.

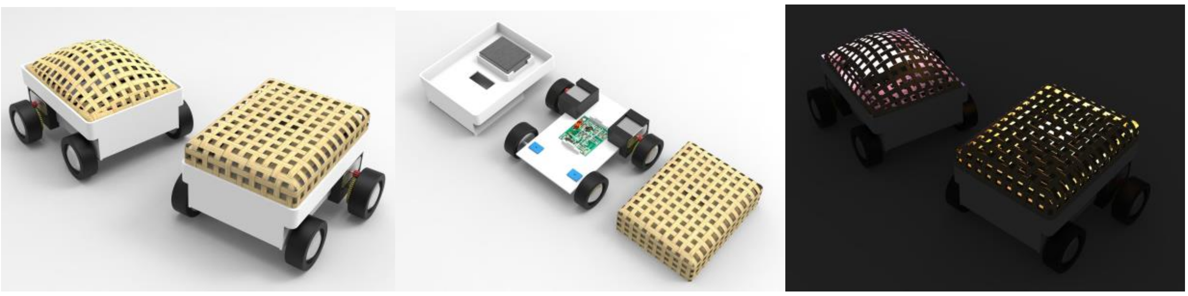

Figure 6. Concept renderings

To demonstrate the cultural knowledge of the technique and encourage users to design their own cars in a unique way, virtual reality (VR) or augmented reality (AR) could be utilized. Utilizing VR or AR technology could enhance the design process by illustrating cultural knowledge and promoting creativity. With AR technology, users can scan the product on their smartphones and enjoy a more interactive and interesting design experience. This would provide a more interesting and interactive platform for users to engage with. Additionally, by integrating AR technology, users could play as a game with their own cars in a virtual world that continues to teach them about traditional crafts and modern techniques.

7 CONCLUSIONS

In conclusion, incorporating traditional bamboo crafts and cultural elements into innovative educational products has valuable potential to promote creativity, cultural understanding, and critical thinking in Hong Kong's education system. The design of tools such as weaving equipment and VR/AR technology can create an engaging and interactive learning experience while preserving cultural heritage. Besides, by integrating traditional knowledge with modern innovations, students can become culturally aware and technologically adapted.

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INTRODUCING HUMANITARIAN CO-HABITATION AS FIRST DESIGN ASSIGNMENT

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ABSTRACT
Against the backdrop of a global displacement crisis of climate and war refugees, the humanitarian? agenda of architecture and the importance of hospitable refugee reception and multicultural co-habitation cannot be ignored. This raises the question: how could this urgent challenge introduce the social agenda of design during the first design assignment for students starting an architectural education? This appears probably even more significant when understanding how a learning process is particularly remembered through the first and last experiences, as bookends of an educational trajectory. This primacy effect ensures that one will not soon forget the very first design assignment that inaugurates an architectural training programme.

For new students, the Bachelor in Engineering Architecture programme developed a ʹstarters afternoon as an introduction to its architectural curriculum. For three hours, freshly arrived students work in groups of four on a design assignment for an emergency shelter. Students are asked to design this shelter as a scale model, proportionally guided by a Playmobil figure, and manually constructed with the use of minimal and predefined materials restricted to wooden sticks, plasticine, rope and paper.
Intermittently, and at the end of the afternoon, all models are reviewed collectively with all students and staff members representing diverse architectural fields of expertise. Here, important aspects like form, function, structure, and construction are discussed, and confronted with societal, cultural and political aspects of design. The 'shelter model assignment' introduces thereby co-habitation and reception as important concerns to kick-off the architectural training of future designers.

Keywords: Co-habitation, care, design education, STEM, design model

1 INTRODUCTION
This paper will underscore the significance of the primacy effect in the selection of a suitable first assignment for new students in architectural design. We reflect therefore on an assignment that introduces co-habitation as a fundamental concern within architectural theory and practice as the very initiation phase and first encounter with design education.
Section 2 will start with a short problem statement. Subsequently, part 3 will explain in a few steps how we arrive at an assignment to design a model for a refugee shelter. After this, we clarify the practical elaboration of the shelter design assignment in section 4. In section 5 we finally evaluate the results of and sketch out possible future steps.

2 PROBLEM STATEMENT: HUMANITARIAN DESIGN AT A ‘STARTERS AFTERNOON’?
Many colleges and universities welcome their new students at the start of the academic year with a starter’s day or even a starters week. On that occasion, a usual aim is to confront candidate-students with the diverse aspects of architectural education. The event serves this way as an introduction to the diverse components and skills of the full programme, while often also inaugurating the first semester courses. Finally, the introduction also aims to inform students about what they might expect to deal with, especially for those who have not yet been able to concretely imagine what the curriculum, or in this case, architectural design, really entails.
At the Faculty of Engineering and Department of Architecture of the KU Leuven, we organise this ʹstarters afternoonʹ as an intensive workshop that immediately invites students to complete a small

design assignment. The assignment is short but profound, geared to raise some of the important structural, technical, and societal questions inherent to contemporary architectural design.
This raised of course the question: what assignment should this be? What should aspirant student be asked to design? Designing what, why, how and for who?

3 REFUGEE RECEPTION AS AN INAUGURAL DESIGN ASSIGNMENT?

3.1 The Primacy Effect: the importance of the very first design assignment

The primacy effect refers to the tendency for individuals to rely heavily on initial impressions, making first experiences especially influential. This means that in a learning process one will mainly remember the first and last experiences. The primacy effect indeed ensures that the first information sticks better, and hence also 'colours' and influences the memory of information that follows. The regency effect in turn ensures that the very last information is relatively well remembered. One suggested reason for the primacy effect is that the initial items presented are most effectively stored in long-term memory because of the greater amount of processing devoted to them. The first list item can be rehearsed by itself; the second must be rehearsed along with the first, the third along with the first and second, and so on.. [1] Consequently, it appears of principal importance for a training program to carefully consider which design assignment is mobilized to initiate a training trajectory. In architectural education in particular, the primacy effect does not only imply that the first assignment will leave a fundamental imprint in the memory of future architects, but also influence the way in which further educational and professional commitments are processed and perceived.

3.2 Refugee shelter as a contemporary design challenge

The above raises the fundamental question: what are the most acute contemporary challenges for architectural design on a global scale? In a context of soaring inequality, ecological collapse and mass-displacement, the perdurance of violent wars, worsened by a planetary environmental crisis, threatens human society at an existential level [2]. Not only human conflict, but also the consequences of global warming, including mounting natural disasters, desertification, and sea-level rise are displacing more people as ever before from their homes and communities [3]. These people displaced in one place often arrive as refugees elsewhere, in search of safe and stable living conditions [4]. Given the resulting growing need for shelter and reception in Europe, and not the least in the Flemish and Belgian context, the design of humanitarian refugee reception spaces such as emergency shelters, surfaces as an exemplary design challenge to confront students in Architectural Engineering with the social importance and repercussions of technical solutions and propositions.

Figure 1. Frontispiece of Marc-Antoine Laugier: Essai sur l'architecture 2nd ed. 1755 by Charles Eisen (1720–1778). Allegorical engraving of the Vitruvian primitive hut

3.3 The shelter and the 'primitive hut'

The architectural concept of 'shelter' as a foundational building typology is of course rooted in humanity's long-standing search of to make 'home' in the world, relating back to the most primitive and primordial forms of human construction. In 1753 abbé Laugier published the 'Essai sur l'Architecture' [5], postulating what he called the 'true principles of architecture'. To Laugier, these principles are embodied by 'la petite cabane rustique', human's first house, consisting of four poles, four beams and a roof. For Laugier, all architecture imitates this primitive construction, and conversely buildings are gauged as 'good' architecture insofar they resemble the 'cabane' (Figure 1). So, for Laugier; the primordial architectural conception of 'shelter' serves as the prototype of all constructions, underscoring its importance as a relevant 'entry' into architectural theory and design.

3.4 From shelter to dwelling?

In a contemporary echo of Laugier's 'primitive hut', the architectural conception of refugee shelter constructions provokes fundamental questions about minimum protection needs, safety, privacy, construction technique, and so forth. What degree and form of architectural construction is needed to shelter from the elements and from unknown strangers? The shelter thereby incorporates important aspects of architecture like function and construction. But the shelter typology raises also fundamental ontological questions. When does a shelter become a dwelling, and when does a dwelling become home? What is needed to not only provide a temporary 'roof' and protection from the elements, but also accommodate feelings of wellbeing, hospitality, and feeling 'at home' in a space that facilitates, and aids displaced people to rebuild disrupted lives? This way, the design of a shelter provokes some of the most challenging questions that have haunted architectural thinking and design since time immemorial. When does a space becomes a place? How does dwelling turn into living? And how can material form nurture social and societal betterment, or even empowerment?

3.5 From building to architecture?

Besides more quantitative constraints like construction and function, also more qualitative facets of design become recognized as important throughout the shelter design exercise. Is the temporary home up to the scale with the provided miniature figure? Is the resulting structure compact, or instead, spacious? What do students think an 'emergency shelter' should aesthetically look like? Does the design model resonate with a certain architectural style? Modern? Traditional? Is it recognizable and in line with certain trends and design paradigms, or rather exceptional and eccentric? How does one ensure that emergency accommodation evokes the desired associations? Which areas are closed off completely and which are left open or transparent to balance security and privacy, or view and light? Does one design a more universal shelter that can be used flexibly across diverse places; or whether and how should it tailor-fit a distinct location? All these and other questions are discussed with the participating students in intermittent and concluding debate moments, offering glimpses and sneak previews of contemporary debates in architecture and design.

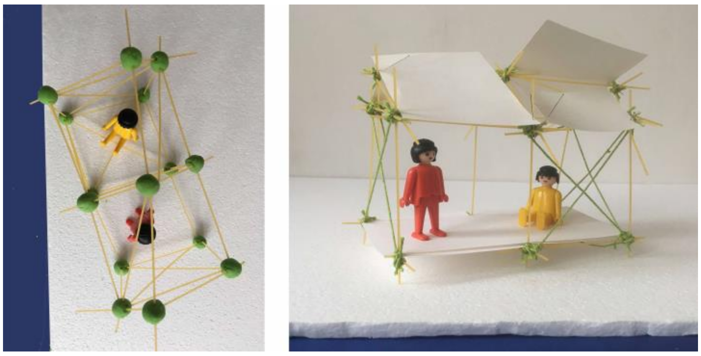

Figure 2. Example of a doll's house for a Playmobil figure

3.6 A Model for a Refugee shelter as assignment

Collins, Brown and Newman, pointed out that in an optimal learning environment, where students can acquire knowledge and skills in an effective way, tasks should be ordered according to increasing complexity and diversity. In such view, a 'good' design assignment for beginners should entail simple constraints [6]. To safeguard feasibility and avoid over-complication, students are not instructed to design a real refugee shelter, but instead, invited to fabricate a physical scale-model for a doll. Although provoking profound and highly complex questions and challenges, the design of a doll's house combines manageability with simplicity, while maintaining a playful and experimental atmosphere. The model is small and easy to make with widely available materials like wooden sticks, plasticine, rope and paper. Simplicity is guaranteed because the students can visually estimate scale-related decisions on the basis of the doll without necessitating actual calculations. (Figure 2) Furthermore, for the assignment of a doll's house, the student is not only the architect, but also the construction labourer, confronting participants with the durability and flexibility, but also the limitations and constraints of certain materials and construction methods [5].

4 STARTERS AFTERNOON

4.1 Beforehand

At the start of the current academic year, we organised a starters afternoon with an assignment for a model for a refugee shelter. Students were asked to bring basic materials and supplies in advance: sticks (for example skewers), plasticine (type 'Play-doh') , a cutting knife , a 'Playmobil' figure, rope (cotton crochet thread), a cutting mat (A4 or A3), pencil and paper for sketching, scissors, and adhesive tape (Figure 3).

Figure 3. Materials and supplies to be brought by the students in advance

4.2 Starters Afternoon: the briefing

At the start of the afternoon students were invited to make a design for a model of a refugee shelter on the basis of a scale model of the 'Playmobil' figure. In a first phase, students were instructed to design and make the structure for a simple 'tent' that could, for example, be used by the figure as an emergency home in an emergency situation. We suggested to use plasticine to create nodes to connect sticks.

4.3 First model: constructional challenges

After the first briefing, students started building with the sticks and plasticine. Quite soon, the diverse staff involved challenged them with questions. Do you use the full sticks, or does the length make them bend easily? If you shorten them by cutting them, how do you ensure that you limit the cutting loss? Is cutting loss waste, and economically lost? After some experiments with the plasticine, we suggested that sticks of the temporary house could also be connected with knotted rope instead of plasticine. In reality and on full scale, the sticks could represent wooden beams that can be disassembled without damage after use by using rope instead of glue, which might make the design more circular and sustainable: the emergency village could now even be moved to a new place if necessary.

4.4 Secondly: Functional challenges

As soon as the first construction with sticks were made, also functional questions popped up. What facilities should be accommodated in the 'emergency house'? Is only space for sleeping necessary? What if the residents would have to stay longer, perhaps weeks, months, or years? What differentiates the 'shelter' typology from housing, and how do we evaluate that distinction? Also, interrogations of different modalities of living together would automatically emerge. What functional spaces could or should be shared between families? Sanitation? Recreation? Cooking? Education? Relaxation? How much privacy is desirable between families and family members?

We suggested to make simple pieces of furniture to scale in cardboard to test how the emergency home could be furnished. Which functions are the minimum necessary to live in a dignified manner? Can certain functions be shared between different families? Or maybe even between existing neighbours and the refugees to be hosted? These purportedly simple questions aim to trigger in fact more existential questions that pervade contemporary architectural debates about housing norms, density, co-housing, emergency housing and the ‘existenz-minimum’.

4.5 Finally: Contextual challenges

We finally challenged students also with contextual concerns. How could they think of a form of emergency housing that is universal on the one hand and could therefore be used flexibly in many places; but may also be able to fit-in well in specific places at the same time? For example, how could a number of emergency housing be accommodated on the open area of the school? Which zone and how much surface of the available open area could be designated for this? How many people could be provided a shelter there? This way, the debate is also steered in the direction of significant urbanism and urban planning reflections that inevitably emerge in actual design commissions, and relate to contextual embedding, the relation between private and public realms, circulation, economic costs, but also participation and public opinion as drivers of decision making.

5 CONCLUSIONS AND FUTURE?

5.1 Debriefing: discussing combined challenges

At the end of the afternoon, all designs were reviewed and discussed together with all the students. Their designs ranged from tents with one small living space to mini houses with several rooms. (Figure 5) Challenges as formulated above were discussed, while also the importance of combined challenges for real design quality were mentioned. (Figure 4) Also, for example, the fact that resources made available for emergency housing are almost always less than the needs in contemporary cities, was debated. The 'challenge' is therefore to design an emergency home that, when applied a specific limited open area, would provide the most 'humane' residence possible, for as many refugees as possible, while at the same time deploying as few resources as possible. Points of debate thus also questioned how certain proposals designed shelter structures as simple/minimal/compact as possible (including through shared functions…), while inevitably having to balance this with an urgent need to provide hospitable and dignified homes for violently displaced populations. Additional discussion focused on building efficiency, including the use and possible reuse of building materials, sustainability, flexibility, etc., while still dedicating attention to living quality and care.

Figure 4. All designs were discussed together with the students

Figure 5. At the end of the afternoon, student designs were reviewed

5.2 Conclusions

The 'shelter model' as a design assignment seems a promising way to confront students with important aspects of the architectural education within the limited time of a few hours. Continuing with similar and variant introductions in future teaching might help to measure the real effect on student learning, exclude a possible overestimation of the primacy effect and compare pros and cons of each assignment. However, in any case, if co-habitation and caregiving are indeed acknowledged as important values for the architectural agenda of increasingly uncertain futures, we argue that it is essential to integrate these core societal challenges into the first design assignments new students are confronted with, as a steppingstone to elaborate on acute global challenges throughout subsequent design assignments and future architectural careers.

5.3 Future

This workshop that was conceived and used for new students starting a design education, is now also taken as the basis for a STEM assignment for even younger scholars in secondary schools. That STEM assignment will be used to introduce these youngsters to Science, Technology, Engineering and Mathematics. Together with an introduction to a design experience, that besides purely technical values, also pays attention to the social and societal aspects. On a cosmopolitan scale.

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SKETCHING ABSTRACTION OF HUMAN FIGURES FOR DESIGN EDUCATION

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ABSTRACT
Industrial Design programmes over the past two decades have modified their curriculum content to address shifting technology, society economies, and expanding opportunities that design can address. Industrial Design has seen great value in the approach of Design Thinking which is reflected in education through course project methodologies where solutions may take a variety of forms beyond that of traditional products by working with a human centred approach. A key aspect to these methodologies is storytelling through the sketch depiction of human figures. Although Industrial Designers have developed techniques and methods to sketch products and often even environments, sketching the human figure bears further investigation. Sketch depictions of humans range from simple doodle figures as a means of brainstorming, to detailed renderings of end users for concept presenting. With figure sketch depiction offering many opportunities in today's Design Thinking climate of storytelling, this paper asks the question "At what level of realism in human figure sketching is optimal for design storytelling?" In the paper we examine the range of sketching humans from extremely simplified to highly realistic and detailed, and what range of abstract to realistic provides designers in today's climate the promotion of idea development and presenting.

Keywords: Abstraction levels, sketching, figure drawing, visualisation, storytelling

1 INTRODUCTION
Today's robust use of storytelling using the human figure for narrative differs from product development of Industrial Design's past. Traditionally, we see the human figure sketched to show scale, ergonomics, and some use narrative when developing products. More often the product alone is sketched without the depiction of human form. The lack of human presence in the depiction of designs was common in the past by architects and designers. The oddness of sketch depictions showing a building devoid of people in the past is mentioned by Colomina and Wigly noting the strangeness of these design drawings to being almost completely devoid of human figures. [1]. In the present day, we see the depiction of human figures as being of central importance in Industrial Design. The value of today's Design Thinking as being 'human centred' and sketching humans in 'storytelling' are central to concepting. Human centred approach started many years ago with the likes of Victor Papanek, then made popular within the field by Donald Norman and more recently by Tim Brown 'Design Thinking' based around a problem statement not just reworking of an existing manufactured product [2].
Design Thinking (DT) puts people first, ahead of the product, it suggests "establishing a personal connection with the people—or users—for whom a solution is being developed" [3]
The importance of storytelling has been established and seen as a needed theme across all design courses. [4]

1.1 Design thinking and visual thinking
"The meaning or essence of the subject is more effectively conveyed by an image than a written or spoken description. Visual aids are powerful tools for conveying information and ideas and for enhancing storytelling".[5] Both Shaw and Paepecke-Hjeltnes underscore the visual representation for remembering and therefore understand the sketched the figure is an important aspect of creating an impression.[6] Simple thumbnail figures can appear in early brainstorming as part of the Design Thinking approach. The need for this in the university is stated by Corremans and Mulder-Nijkamp,

who posit that “students’ sketch competences should extend beyond merely object related sketches and drawings”. [7]

However, most design education institutions have based their educational content regarding visualisation, in particular design sketching, on more traditional approaches that regard the product only. Authoritative books on design sketching such as “sketching” (Eissen & Steur)[8] and “How to draw” (Robertson), showcase this product focus very clearly. Thus, the question arises how to teach the sketching of the human figure for present-day design students.

1.2 Sketch realism

Simple, abstract versions of the figure have been deployed in methods of Visual Thinking in the works of e.g., Willemien Brand to be effective in elevating an understanding and getting ideas flowing.[5] The past decades have seen many individuals and companies producing works of this nature, while others have adopted a somewhat more intricate depiction of the figure. For example, the work of JAM visual thinking or INK strategy show a different level of abstraction.

One aspect of sketching the human figure, which could significantly influence educational strategies on the topic, is the level of realism that is aspired to. The representation of the human figure can vary from abstract to highly realistic. Perhaps somewhat counterintuitively, it is not certain that a less realistic depiction equals a less effective design sketch. UX designer Komarov, for instance, considers how much realism doesn’t actually add to the content, but the importance lies in “communicating your ideas as quickly and as clearly as possible, not drawing pretty pictures” [9]We understand that realism may not be better. In fact, it might be worse. Too much realism might actually have a negative effect on the narrative quality of the sketch, especially regarding the figure. The comic book artist Scott McCloud offers the following diagram of a person’s face from abstract to detailed realism (figure1). McCloud argues that “By stripping down an image to its essential “meaning” an artist can amplify that meaning in a way that realistic art can’t.” [10]

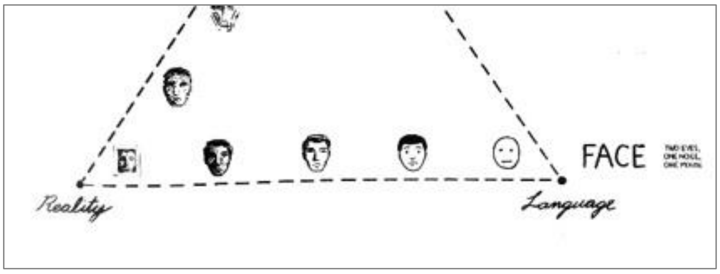


Figure 1. Levels of facial abstraction (cropped from McCloud's original)

Based on the abovementioned, we propose a chart which maps the realism level of the figure from simple/abstract to highly detailed/realistic.

Applying this idea to sketching for design purposes, one could consider the ‘characterisation’ of the user as a “best practice” [4]. If best practice in sketching is regarded as sketching both effectively as well as efficiently, we could plot the effectiveness of the sketch versus the amount of time and effort needed to create it. With correct methodology, one could induce a large part of the effect with minimal expenditure of time and effort (figure 2). In sketching and drawing, the best practice would thus result in a curve of asymptotic character shown in figure 3, where the realism levels have been mapped onto this hypothetical curve.

Thus, this paper puts forth the question “What level of realism in human figure sketching is optimal for design storytelling?” Considering the curve from figure 3, where figures are depicted from highly abstract to high realism, suggesting that too much realism scale would not be considered ‘best practice’. With too little effort a simple abstract stick figure sketch does not purport enough narrative, while too much effort would yield only very little additional narrative quality for a large investment of time and effort. Therefore, the authors hypothesize that some middle level of realism should be optimal. This level allows the optimal balance of sketching quickly without adhering to a high level of realism.

Figures 2 & 3. A range of realism, and plotting narrative vs. time

2 METHOD

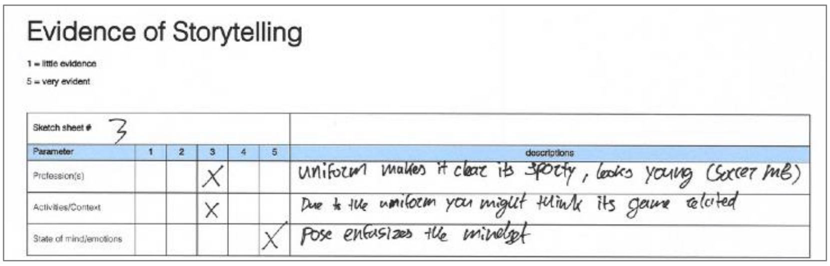
To test the hypothesis, thirty Industrial Design Engineering students at TUDelft participated in a workshop study. The participants, with a varying range of seniority and sketching skill level were given two tasks. The first task was to produce sketches with the aim to convey a particular narrative. The second task was to assess their peers' sketches on the narrative quality. Each participant was assigned a number, which was noted down by the assessor during the assessment task. This way it was clear which assessment pertained to which sketch sheet.

2.1 Task I: Persona sketching

Arriving students were asked to take a seat at an individual desk with sketch paper with a sticky note on the desk corner having a number on it. The authors introduced the nature of the research with examples of sketched of human figures as depicted in design, including the chart of figure abstraction level by the authors. No mention of our hypothesis was suggested. The participants were then asked to establish a persona describing three narrative characteristics: 1) profession, 2) activity/context and 3) state of mind/emotion. Without the use of text, the participants were then assigned the task of visually depicting this persona through sketching, the participants could sketch in their own comfort level, yielding a range of different levels of complexity, realism and detail in the results. Participants filled at least one sheet with multiple sketches, iterating on the depictions of the same persona they had decided upon. They were asked to note down, covertly in order to remain hidden from peers looking at the sketch sheet, the three characteristics of their established persona.

2.2 Task II: Peer assessment

With the first task completed, the participants were now tasked with assessing their peers' sketches of personas. On a scale from 1 to 5, they were asked to rate how evident they found the three persona characteristics to be present on the sketch sheets. Figure 4 shows the assessment form handed to the student to complete this task, fille in by one of the participants. This assessment sheet was filled in for three peers by every participant, so that every sketch sheet would be rated three times by three different peers. Each reviewer asked to rate the effectiveness of profession, activity/context, and state of mind/emotions.



Evidence of Storytelling

1 = little evidence
5 = very evident

Sketch sheet #	3					
Parameter	1	2	3	4	5	descriptions
Profession(s)			X			uniform makes it clear its sporty, looks young (soccer mb)
Activities/Context			X			Due to the uniform you might think its game related
State of mind/emotions					X	Pose enfasizes the mindset

Figure 4. Example of a sketch assessment form from the study. Top left, the sketch sheet number of the participant being assessed is noted down

3 RESULTS

Each student's sketch (with assigned number1-30) with the three peer reviewers scores were compiled. See figure 5. Due to practical limitations, only the overall average scores were considered in the results, which are shown in the dark green column. Based on this overall average score, the top three rated sketch sheets were compared to the bottom three. The chart in figure 5 shows the sketch sheet numbers, their assessment ratings and averages for characteristics as well as overall averages. Three of the thirty sketch assessments were not used in the analysis due to missing or incomplete reviews.

sketch sheet #	characteristic	assessment 1	assessment 2	assesment 3	CHARACTERISTIC AVERAGE	OVERALL AVERAGE
1	P	4,5	5	5	4,83	4,06
	A	5	4	5	4,67	
	S	5	1	2	2,67	
2	P	4	5	4	4,33	4,33
	A	4	5	5	4,67	
	S	3	5	4	4,00	
3	P	3	3	5	3,67	3,67
	A	3	2	5	3,33	
	S	5	2	5	4,00	
4	P	5	4	4	4,33	4,00
	A	5	2	4	3,67	
	S	5	5	2	4,00	
5	P	1	2	4,5	2,50	3,28
	A	3	4	5	4,00	
	S	2	4	4	3,33	
6	P	5	5	5	5,00	4,22
	A	5	5	5	5,00	
	S	3	2	3	2,67	
7	P	5	5	5	5,00	4,33
	A	5	5	5	5,00	
	S	3	3	3	3,00	
8	P	3,5	4	5	4,17	4,50
	A	4	5	5	4,67	
	S	4	5	5	4,67	
9	P	5	5	5	5,00	4,50
	A	5	3,5	5	4,50	
	S	3	5	4	4,00	
10	P	2	2	3	2,33	2,83
	A	4	3	4	3,67	
	S	3	2	2,5	2,50	
11	P	5	5	5	5,00	4,33
	A	5	5	5	5,00	
	S	3	3	3	3,00	
12	P	5	5	4	4,67	3,89
	A	4	5	3	4,00	
	S	3	4	2	3,00	
13	P	1	3	4	2,67	3,44
	A	1	4	4	3,00	
	S	4	5	5	4,67	
14	P	3	5	2	3,33	2,83
	A	2	4	1,5	2,50	
	S	4	3	1	2,67	
15	P	2	5	5	4,00	4,33
	A	5	5	4	4,67	
	S	4	5	4	4,33	
16	P	2	3	4	3,00	2,78
	A	4	1	4	3,00	
	S	2	1	4	2,33	
17	P	5	5	5	5,00	3,89
	A	3	4	5	4,00	
	S	2	3	3	2,67	
18	P	3	2	1	2,00	3,78
	A	5	4	5	4,67	
	S	5	4	5	4,67	
19	P	1	1	2	1,33	3,22
	A	5	5	5	5,00	
	S	3	4	3	3,33	
20	P	5	5	5	5,00	4,78
	A	5	5	5	5,00	
	S	5	4	4	4,33	
22	P	4	4	4	4,00	2,89
	A	2	3	2	2,33	
	S	3	1	3	2,33	
23	P	5	4,5	5	4,83	4,61
	A	5	5	5	5,00	
	S	4	3	5	4,00	
24	P	1	2	5	2,67	3,67
	A	5	5	5	5,00	
	S	4	3	3	3,33	
25	P	2	1	2	1,67	2,22
	A	3	1	4	2,67	
	S	2	2	3	2,33	
27	P	4	2	3	3,00	3,89
	A	5	4	5	4,67	
	S	4	4	4	4,00	
29	P	5	5	5	5,00	3,67
	A	3	1	3	2,33	
	S	4	3	4	3,67	
30	P	5	3	5	4,33	4,56
	A	5	5	5	5,00	
	S	5	5	3	4,33	

Figure 5. Assessment of the sketches for profession (P), activity (A) and state of mind (S) with three assessments for each sketch sheet. The light green shows the average assessment score for each characteristic and the dark green shows the overall average score

3.1 Analysis

Ranked from highest to lowest overall average rating, sketch sheet numbers 20, 23 and 30 rank as the three highest rated. Sketch sheet numbers 25, 16 and 14 rank as the three lowest. Figure 6 shows collage of the three highest and three lowest rated sketches, with the top row showing the highest and the bottom row the lowest. Comparing the top and bottom three assessed sketches, the authors looked for similarities between the top three which were not apparent in the bottom three, and vice versa.

Firstly, the top 3 sketches all show a mid-range level of realism and detail, comparable to level 3 to 4 of the chart in figure 2 discussed previously. In comparison, the bottom 3 sketches show the figure at an abstracted level, two students using hardly more than stick-figure depictions, very similar to level 1 to 2 of the figure 2 chart.

Second, the figures in the top three sketches all interact with a clear, identifiable tool or contextual prop. Props and contextual factors are visible in the bottom three sketches as well, yet their depiction is abstract or ambiguous, either of a more abstracted nature or not specific at all. For instance, the cube on a table in sketch #25.

Third, the top 3 sketches show more facial features, whereas 2 of the bottom 3 hardly show any.

Furthermore, the top three sketches seem to make an effort to depict the figure as a 3-dimensional entity rather than a 2-dimensional and almost abstracted entity. The sense of perspective, overlap and posture or gesture is generally more apparent and more "life-like" compared to the figures in the bottom 3 sketches.

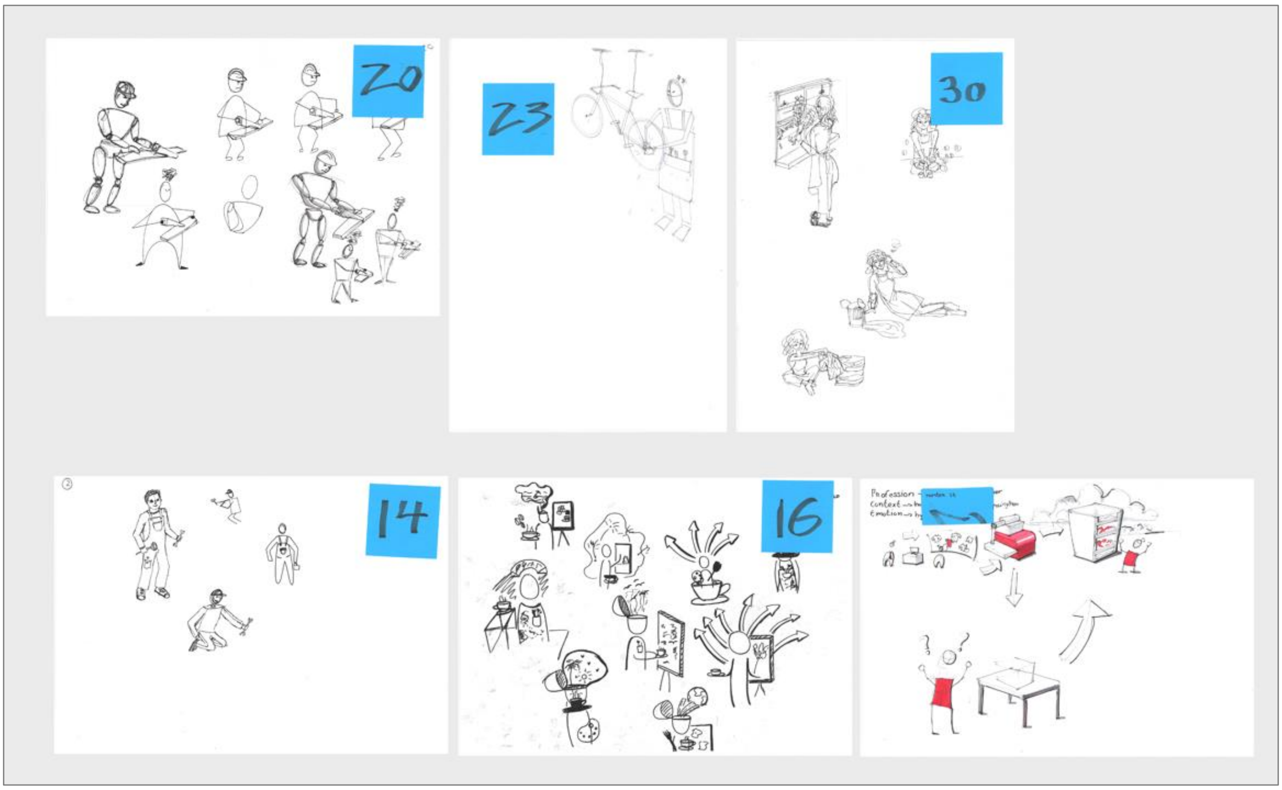


Figure 6. Collage of the 3 highest rated sketches (top) and the 3 lowest rated sketches (bottom)

4 CONCLUSIONS

In conclusion, our hypothesis appears to be supported by the results of this study. It is indeed likely that there exists a lower bound with regard to simplicity or abstraction of the figure, if the goal is to convey characteristics of a persona. Elements that seem relevant to incorporate to at least some extent are:

- Facial features, which most likely serve to boost the narrative quality regarding emotion.
- Tools, props and/or contextual elements, which act as visual cues regarding the profession, allowing for the opportunity to adopt in the figure a certain position or movement which aids in conveying the particular activity.
- Detail in the attire of the persona
- The depiction of a specific pose or movement in the figure
- The depiction of the figure as a 3-dimensional entity, regarding environment and perspectival cues.
- A stick-figure like depiction, especially one without any recognisable facial features, runs the risk of falling short with regard to narrative quality.

5 DISCUSSIONS

The study knows some limitations. Firstly, not all the data was analysed. Only the overall average score was investigated. It would be interesting to investigate characteristic scores specifically and see whether those sketches show distinct commonalities as well. Of the 27 sketches, only 6 were analysed as they represented the most successful and least successful narrative sketches. The limitation makes this only a qualitative investigation of the results.

With regard to the task, it appeared that some participants had misunderstood the task. some unforeseen variances in the results, particularly in the number of sketches. With regards to simplification, what should not be overlooked in education, is the notion that simplifying a sketch does not necessarily mean that the sketch is easier to do. As a design sketching practice, it could often be seen that simplification can actually be harder but is nonetheless important as simplification enhances the narrative. [11] So, with that in mind, nothing conclusive can yet be said about the difficulty level of sketching the figure in design education.

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LEARNING TO MAKE SENSE: SKETCHNOTING IN UNDERGRADUATE DESIGN EDUCATION

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ABSTRACT
This paper outlines a pedagogical approach based on "sketchnoting" to help design students gather, synthesise, and make sense of information. The method combines theory on how people learn with theory on how designers typically think to develop a form of studying, research, and sensemaking that is useful for both the course and lifelong learning. Based on dual coding theory, the method suggests creating two representations (visual and verbal) of complex information to facilitate sensemaking. A visual note-taking system, adapted to designers' thinking, provides a helpful bridge between disciplines with different epistemological foundations but is not without challenges. Objective evaluation of a highly personal sensemaking method is problematic, and students with a background in visual arts may be better prepared to use it. The paper will discuss these issues and relate them to the future challenges that design education must face.

Keywords: Sketchnoting, design education, dual coding, visual thinking, semi-structured interviews

1 INTRODUCTION
Designing is an unstable process that requires designers to make sense and integrate information from various sources. Faced with the wicked challenges of design, a designer must combine fragmented knowledge to create new things; in this sense, design represents an old new way of learning [1]. Sketching and modelling have long been used to collect information and think through design challenges [2]. Throughout their careers, experienced designers develop strategies for negotiating practically and cognitively with the materials they work with [3], including the means to collect and make sense of information through visual means.

However, designers in training lack the benefits of that practice, particularly first-year undergraduate students. Nevertheless, these students are still expected to make sense of complex problems and develop potential solutions. Throughout an undergraduate programme, information streams are many, unstructured, and diverse. Concepts and methods arrive from different knowledge traditions and disciplines. For instance, while working on a digital design project, a student may require inputs from Ergonomics, Cognitive Psychology, and Interaction Design; and even though the student may be able to grasp the key concepts offered by each subject, it is by integrating them while developing a solution that information becomes meaningful.

Research has shown [4] that combining verbal and non-verbal information can enhance learning and memory. Students who are presented with ideas using a combination of text and diagrams tend to grasp the material more effectively than when taught using either one of these formats alone. Furthermore, as Edward Tufte [5] argued, the most effective way to understand complex information is in relative and visual terms (through contrast, positioning, and proportions), which help to uncover meanings that would otherwise remain scattered in numerical tables.

This paper describes our experience with a pedagogical intervention combining theory on how people learn and how designers typically think [6]. The intervention was developed to help students acquire a method for synthesising and making sense of information, both for studying and as part of their future professional toolkit. The intervention is grounded on sketchnoting [7], which requires students to develop a personal system of visual notetaking as part of their evaluation.

The paper discusses data obtained throughout one semester from an undergraduate design programme structured around Project-Based Learning (PBL). In a PBL system, all courses support and participate in the core project curricular unit. In this context, integration of knowledge is vital as it is how the students are evaluated in each course. Students must demonstrate that they integrated the various sources of knowledge into a coherent design project. We combined semi-structured interviews and an online questionnaire to investigate the usefulness of sketchnoting as a method for helping students synthesise and make sense of information.

This is the problem and the underlying theory that supports our pedagogical intervention. The question is, did it work? In theory, a visual note-taking system adapted to designers' typical thinking patterns should help to connect disciplines with different epistemological foundations. Although the approach has its benefits, there are also challenges. It can be difficult to objectively evaluate a sensemaking method that is highly personal, and students who lack a background in visual arts may face difficulties when using it. Also, to what extent was the tool effective? Will students embrace it and integrate it as part of their toolkit after they leave school?

2 SKETCHNOTES AS DUAL CODING

Mike Rohde [7, p.2] defines sketchnotes as "rich visual notes" where handwriting, sketching, lettering, and diagrammatic elements such as arrows, boxes, lines, and geometric forms are combined. The technique is varied, and Rohde's method is not the only one available; nonetheless, all variations are typically based on a modular set of primitive forms (squares, circles, triangles, and lines), which practitioners can combine to create a more complex visual toolkit.

Sketchnotes are about summarising information—conveyed through lectures, talks or any other means—in one or two pages; they require highly developed listening skills to analyse, synthesise and discriminate non-essential data. Sketchnotes take advantage of dual coding [8]; hence they allow the practitioner to create a "visual map" where images and words are cross-referenced to better portray complex ideas through visual metaphors [7], [9]. As a result, visual notes reportedly improve comprehension, retention, and recall of information [10]. Sketchnoting is a note-taking method that emphasizes visual concepts and is more efficient than linear written notes, as images can condense information effectively. However, it is important to clarify that sketchnotes are personal documents and not infographics meant for a broader audience. While they may be shared with others, it is important to differentiate them from graphic recording, which focuses on visual communication for third parties and shares many similarities with sketchnoting.

Adding visuals to a verbal description clarifies an idea. However, true dual coding involves more than adding pictures to words. The visuals must have meaning and not serve as decorations. Allan Paivio's [8] research suggests that learning and memory improve when verbal and visual representations are used in tandem. For instance, when an unfamiliar word is introduced, the learner often creates a mental image of the concept or object represented by the word. This mental image is then associated with the word itself, forming a dual representation that can be accessed when recalling the information. This connection between verbal and visual representations enhances the encoding and retrieval of information, making it a vital component of effective learning strategies.

3 METHODS

During the initial part of the semester, three sets of first-year students enrolled in our English-language, internationally oriented undergraduate design course were taught about sketchnoting as part of the "Design Methodology" class. Although the introduction was brief, students were given additional materials to study. To improve their sketchnoting abilities, students were required to create one sketchnote per lesson. By the end of the semester, they were expected to submit a larger sketchnote that showcased how they utilized their knowledge in their project.

Crucially, the course is entirely based on PBL, which means every semester is organised around a single project to which every curricular unit contributes. As noted elsewhere [11], this course is grounded on a conception of design as an interdisciplinary endeavour and, therefore, with no fixed subject matter. Such a holistic view of design is embedded in the course's name: "Global Design." Throughout this programme, we encourage students to re-frame design problems interdisciplinarity rather than expecting them to respond mechanically to a brief. Although some influential views on design education downplay the importance of drawing skills [12], we believe that the capacity to externalise ideas through sketching plays a vital role in thinking through a design problem.

Nonetheless, it is true that the type of drawing skills which students acquire before entering our course is not ideal since students focus on observation and realistic rendition of reality (i.e., academic drawing) instead of focusing on concept representation (i.e., sketching).

To gain a baseline understanding of our students (and their drawing skills) before the pedagogical intervention, we asked them to respond to a quick survey and obtained N=70 responses (out of a universe of 75 students). From this survey, we learned that most respondents (60%) were Portuguese nationals, although some students came from Nigeria, Germany, South Africa, Israel, Mozambique, and Brazil. An overwhelming majority of the sample were female (77%), and the majority were 18 years of age.
Regarding their academic background[1], 70% of students came from the Arts domain, and 13% came from the Sciences. This implies most of them had a few years' worth of artistic education and, therefore, of drawing. However, only ~25% admitted to drawing "very often" or "always" (see Table 1 below).

Table 1. Breakdown of the self-reported drawing habits of students before the pedagogical intervention after answering the question "How frequently do I draw."

Never	Rarely	Sometimes	Very Often	Always
n/a	22,9%	51,4%	22,9%	2,9%

After the intervention, we interviewed two design students, and analysed the interviews using thematic analysis. The online questionnaire was distributed to all first-year design students (resulting in N=44 responses) and included Likert-scale-type questions. The data collected from the two methods were complementary, aiming to generate insights into the students' experience with sketchnoting. The data analysis involved descriptive statistics and thematic analysis, allowing for a comprehensive understanding of the data.

3.1 Data Collection and analysis

3.1.1 Data Collection

We conducted semi-structured interviews with the participants (N=2) to better understand their perspectives on using sketchnotes to make sense of lectures. The interviews were conducted in person, lasted approximately 30 minutes each, and were audio-recorded with the participant's permission. In addition, the interviews were transcribed verbatim for analysis. Furthermore, we sent an online questionnaire to all first-year design students (N=44) to gather their opinions on the usefulness of sketchnotes in making sense of lectures.

3.1.2 Data Analysis

Thematic analysis was used to analyse the semi-structured interviews with the two design students. The analysis involved familiarising with the data, generating initial codes, searching for themes, reviewing and refining themes, and defining and naming themes. The analysis was conducted by two researchers independently, and any discrepancies in the analysis were discussed and resolved. The online questionnaire data was analysed using descriptive statistics, including frequencies and percentages, to summarise the participants' responses.

4 RESULTS AND DISCUSSION

4.1 Interviews

For the interviews, we asked students open-ended questions about their design process and how they managed information during the first semester. It is clear (and encouraging) to notice that first-year students reflect on their design process. Paraphrasing Schön [3], we can say they reflect on action. For instance, students revealed a concern about the role of research in the design process and the difficulties of overcoming creative blocks. Also, one student mentioned how the course changed her way of looking at the world increasing her curiosity: *"it's so interesting to see things that people don't even realise*."
The semester project emerged as the anchor that allowed them to make sense of the input from the semester's curricular units. The project acts as a filter; if the information cannot be applied to the project or used to support idea generation, it is discarded. For instance, a student mentioned that he *"was trying to see how I could take anything from her [another teacher's] class and add it to my project."* This

[1] In Portugal, when they turn 15, students in public high schools are divided into four knowledge areas: Sciences and Technologies, Socio-Economic Sciences, Humanities and Languages, and Visual Arts.

could be a concerning insight; during a university course, students should grow in curiosity and knowledge about the world. Knowledge should not be a means to an end but something with inherent value (even if not immediately applicable), and learning is worthwhile. On the other hand, we can argue that a design project works almost like a synthesising apparatus, a pedagogical experience that encourages students to work through and make sense of information. The role of the teacher could be a key aspect here, as one student mentioned, *"sometimes thanks to the teacher, I find something even better. Something which I would not have if I did not have her guidance."*

Sketchnoting was highlighted as a helpful memory aid; one of the interviewees mentioned that *"sketchnoting is better for me because when I see it I can remember what the drawing was about."* While another student stated: *"I did start using sketchnotes and it did actually help me go through where I started actually writing notes alongside the drawings. And I realised as I would go through my sketch notes, and notice 'oh, this was a little drawing I did in this class because of this'. And so, I started doing memory associations with it. So, it helped with recall."*

However, there were no explicit references to the role of sketchnoting in combining disparate information into a coherent whole. Both students were surprised at what the teachers expected from their sketches. In secondary school, drawing meant technique, skill, and artful renditions of visible reality. Some students appear to be formatted by this perspective and are worried about creating impressive renderings instead of considering sketching as a thinking tool.

4.2 Questionnaire

A significant majority (77,3%) of students reported having prior experience with drawing. However, this does not imply that sketchnoting is easier for individuals with prior artistic skills; in fact, both interviewees stated that their prior experience with drawing focused on artistic perfection rather than using drawing as a tool to think. Which somewhat limited their willingness to take on sketchnoting.

Most students considered sketchnoting useful to make sense of or understand the course lectures (54,5%) and helpful to summarise the information from multiple lectures (59,1%). Here the interviews help us interpret this data: students' approach sketchnoting primarily as a memory aid, that is, to remember the course material. However, *remembering* is only the base level of learning outcomes; the subsequent levels include understanding, applying, analysing, evaluating, and creating [13].

This suggests that students disregard the role of notetaking as a thinking tool. Notes are the building blocks of deeper thoughts [14]; they support the burden of reasoning and reflection the same way Lego blocks support a Lego model. A designer sketches a great deal before moving on to CAD; likewise, writers work on their notebooks before tackling a first draft. Of course, a personal note-taking system helps capture information; but notes are not an end in themselves. Instead, their added value supports more profound, integrated, and creative ideas.

When we connect different pieces of information through personal notes, we create a web of knowledge that allows us to see relationships and patterns. This can lead to aha moments [15] and creative breakthroughs as we make unexpected connections between seemingly disparate concepts. Experts work like this, focusing on the process, not the end goals; first-year students, on the other hand, appear to be entirely focused on the outcome. They are defensive and perfectionists and resist showing their work in progress to their teachers.

The data supports this observation. Notice that, while most students recognise the usefulness of sketchnoting, only 31,8% report an intention to keep using it. Furthermore, most students (75%) only used sketchnotes in mandatory exercises, which indicates that design students do not recognise the value of using this tool regularly. Perhaps because students perceive sketchnoting as time-consuming and challenging, and they may need to acknowledge the long-term benefits of using sketchnotes beyond their coursework.

5 CONCLUSIONS

Students recognised the usefulness of sketchnoting for summarising course material and aiding memory. Still, they tended to approach notetaking to retain information rather than as a tool for deeper thinking and creative insight. That is concerning because notetaking can help students develop insights and connections between concepts. Additionally, the fact that most students only used sketchnotes for mandatory exercises suggests they do not recognise the value of sketchnoting as a regular practice. Educators should aim to help students understand the benefits of sketchnoting beyond their coursework and encourage them to use this technique for integrated, interconnected, and creative thinking.

Another takeaway concerns the broader methodological implications regarding how students understand the design process and the role of tools within it. On the one hand, students understand that tools such as sketchnoting are effective in helping them acquire knowledge; on the other hand, they report they will not appropriate the practice or use it in the future. Whether this perception will change is open for discussion, and future assessment will need to be carried out to understand the roots of the contradiction. For the time being, we may speculate that one of the reasons explaining the student's reluctance to embrace visual notes fully is the way they understand drawing as an end goal rather than a tool. That is to say, they are not focused on the process but on a satisfactory outcome that must be aesthetically pleasing. This view has perhaps been entrenched in their minds and heavily reinforced by their artistic training in secondary school, where drawing is not treated as an instrument but as a discipline in its own right. Hence, when exposed to sketching as a quick, messy process, they may enter into a state of cognitive dissonance, further preventing them from embracing it.

These findings raise questions about how educators can encourage students to incorporate sketchnoting into their learning strategies and how to emphasise the benefits of using it in their design process. The findings also suggest that educators must address student misconceptions about the effectiveness and value of drawing for design and its relationship with the iterative development that is inextricable from design practice.

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ROCKIN' AROUND THE PROTOTYPE: AN EDUCATIONAL EXPERIMENT OF COLLABORATING WITH A USER INNOVATION COLLECTIVE

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ABSTRACT
The paper discusses the importance of real-life context in design education and presents a case study on the coordination of stakeholders' interests around a prototype through the lens of design research and teaching. Collaboration with user innovators exposed design students to real-world challenges and constraints that they would not have encountered in the classroom. The study highlights how experiential knowledge is generated through collaboration between academics, practitioners, and specialists from various domains. The paper describes the study context, the primary human and technological actors, and the knowledge domains involved. It concludes by discussing the results and addressing strategies for future research and implementation, including educating individuals to recognise and respect professional boundaries.

Keywords: User collective, prototype, codesign, electric snowmobile, Arctic design, design education

1 INTRODUCTION
Essentially, design education as a relational and context-dependent practice [1] constantly requires up-to-date direct links to the 'outer world' to encourage diverse societal interaction, deeper understanding and solving problems for real-life contexts [2]. In the industrial design and engineering domain, it is of particular importance to teach would-be professionals by utilising a collaborative approach where all the stakeholders are present – including various experts who inform the process at the different stages – and engaged in real-life research and development activities throughout the entire project [3]. However, in an industry context, it is a rare instance when students are admitted to taking part in real projects. Also, in such a context, successful design – from problem definition to final design implementation – is a time and resource constrained activity, which hardly could fit in a typical educational cycle. To approach the complex issues at hand, we present a case study involving a handcrafted metal framework prototype of an electric vehicle for extreme terrains. This prototype enabled a multi-actor collaboration between enthusiastic developers and users, academics (experts in design and control science), and industrial design students and teachers. The prototype served as a hub for diverse activities among various stakeholders and product contributors, leading to the development of innovative ideas and refinement of individual paths. Through this collaboration, participants were able to gain new insights into the challenges faced by each other, resulting in a more comprehensive approach to addressing the issues at hand. By working together, stakeholders were able to identify new opportunities for innovation and develop solutions that would not have been possible through individual efforts alone.

The paper is structured as follows: The second section outlines the employed data and methods. The next section describes the study context, the primary human and technological actors, and the knowledge domains involved. The case study is presented in Section 4, which focuses on the coordination of stakeholders' interests evolving around the prototype and relevant outcomes through the lens of design education. The conclusion of the paper contains discussion of the results and addresses strategies for future research and implementation.

2 METHODS AND DATA

The study began as experiential making when the first working prototype of a light electric snowmobile was made in 2019. Since then, a place-based approach has been employed to advance the prototype through a series of field tests and changes made on-site. The research timescale of 2019–2022 also encompasses the valley of death, i.e., the institutional, financial, and skill gaps in the transition from an existing or emerging technology to the creation of a compelling new market-driven business [4]. Usually, because of this gap between development of science and development of commercial products, many opportunities to create technology ventures remain undeveloped and unexploited, and some products never even get to the point where a designer can work on them. In our case, however, the design and styling phase was able to happen during the valley of death period because of the connections between stakeholders that this paper describes.

The study uses ethnographic immersion and qualitative data collection based on semi-structured interviews in various localities – from manufacturing workshops to potential settings of use – with developers, potential users, and testers (n = 18), as well as participant observations (riding prototypes and working closely with makers at the manufacturing facilities).

At the stage of designerly work, using the place-based approach of the Arctic Design School [5], the qualitative data collected was used to make a series of design proposals for how future overland electric vehicles for remote northern areas might look. "Design classics" [6] such as designing by metaphor, low-fidelity prototyping, user profiling, and intensive sketching were employed during the design phase.

3 THE CONTEXT AND THE PRIMARY ACTORS

In the background, there were three independent storylines that eventually intertwined. (1) of the team of university-based design researchers from the extreme environment design lab who won a large 5-year grant (Russian Science Foundation No. 17-78-20047, 2017-2022) for exploring, grounding, and teaching Arctic design as a new field of design theory and practice for remote and sparsely populated regions with extreme environmental conditions [7]; (2) of control scientists from the lab of active systems specialising in formal modeling and complex evaluation mechanisms; and (3) of a startup of enthusiast tinkerers. In this paper, we illuminate just a part of these collaborative encounters between science, technology, and education related to interactions with a physical prototype of an electric snow vehicle named *S-bike*, with a focus on its educational relevance.

3.1 The Company

The case company, i.e., E-Max Laboratory of Electric Transport (hereinafter E-Max), is initially a user collective specialised on customisation and electric conversion of standard vehicles, predominantly motorbikes and formally established as a small enterprise in 2013. The breakthrough occurred in 2014, when E-max team conducted a successful conversion of a gasoline Yamaha 450 into electric version, which later, in 2017, passed several stages of the international Africa Eco Race 2017. It was the first electric motorbike appeared at the international class rally. Over the next four years, there were other successful conversions from gasoline to electric conducted, including several dirt bikes and street motorcycles, as well as cars and ATVs. Since 2020, the company has been manufacturing its in-house development DWX 250 awarded the best electric enduro in Russia in 2021. Today, the company employs about 10-15 people (depending on the ongoing volume of orders).

3.2 The Prototype

The main technological actor, so-called S-bike, is a working prototype of a lightweight mini-snowmobile with a front ski and a narrow track with an electric wheel-motor unit inside that reaches a maximum speed of 70 km/h. It contains a compact battery (there is a space for two units) with one-charge cruising range of 50 kilometres.

S-bike is the result of the efforts of a small group of enthusiasts to implement the concept of developing a relatively light and compact electric-powered vehicle for driving upon snow. The idea of such a vehicle emerged among two friends and passionate snow riders while experimenting on lightweight structures in their garage in 2017-2018. One of them was a gifted engineer and tinkerer and another one was a technical scientist and a senior researcher at the Institute of Control Sciences, who also engaged successful structures as subjects of automation tests in his lab. They initially attempted to equip a fat bike (an off-road bicycle with oversized tires) with an electric motor, and it was able to operate. However, it was only useful on the rolled path. It was futile to attempt to ride it in the deep snow. It implies that it is necessary to forego wheels, if not make them as massive as for off-road vehicles. In the meantime, there has been a tried-and-true way to move on low-bearing surfaces, like snow, for a long time: it is the track. On a standard motorcycle, a specialised track set can be installed to create a highly functional vehicle.

In early 2019, the inventors approached E-Max company with the idea of electrification of their snow machine. The technological challenge was accepted, and soon E-Max supplied a kit for electric conversion that included a traction electric motor, a battery, and a controller with controls. In summer 2019, the first workable prototype was developed and tested in Mount Elbrus, the highest peak of the Caucasus Mountains. However, the battery collapsed (exploded) shortly after the ride has started, but that accident, in fact, inspired the team to continue experiments. Since a workable prototype has been made in the end of 2019 (Figure 1), the multi-actor collaboration has begun and centred around it. First, the inventors of the first version of the S-bike joined the E-Max team and set up a joint manufacturing facility. Mathematicians also joined the design researchers to work on a state-funded multidisciplinary research project [8], and the design researchers, who are also teachers, created a Master's-level course and launched a students' contest about electric-powered Arctic mobility.

Figure 1. The S-bike prototype. Image credits: Nikolai Korgin

4 CASE STUDY

Working with and around the prototype was accomplished in multiple directions simultaneously. Below, we consider each direction within its primary group.

4.1 Researchers

A state-funded project by the academic community of design researchers and control scientists (mathematicians) laid the methodological and financial groundwork. This project made it possible for expeditions and test trials, field research on potential audiences and users, and the discovery of new, unexpected audiences, like reindeer herders, mountain rescuers, and even special forces.

4.1.1 Outcomes

During the two years of the project (2020-2022), the research team went on three field trips: one to the North Caucasus and two to the Kola Peninsula. On these trips, the S-bike was tested in potential target (climatic and infrastructure) conditions of use, and surveys were done using structured and semi-structured interviews and participant observation to find out what tourists, researchers, and representatives of the indigenous community need with regard to individual mobility. The expeditions' overall results are as follows: A qualitative assessment of the design and engineering proposals was conducted with the participation of the ATV manufacturers and potential users in the test localities of the North Caucasus and Khibiny Mountains (alpine skiing complexes) and the tundra (reindeer-herding bases), which revealed, on the one hand, fundamental mistakes made during the design and assembly, i.e. redundancies of development as judged by individual criteria, and, on the other hand, confirmed both the adaptability of the chosen format of manufacturing, i.e., a small innovative enterprise, and of the product, i.e., a small-sized vehicle, that gives a user a degree of control in extreme situations of failure.

Through the research project, funds were also made available (indirectly) for concept development by the lead designer, who was a member of the design research team, and for "homebrew prototyping" in the studio, and for student internships at manufacturing facilities.

4.2 Users-makers

When the prototype was created, the design and styling phase began. The manufacturing company needed to design a marketable product so that the first batch could be produced and successfully sold. At that point, it transitioned from a user collective to "developer immersion in use," one of the most effective strategies for finding inspiration when creating something new [9]. This strategy places a premium on the designer's experience in the user's domain, or the context in which the product or service is utilised. In the case of the S-bike, the initial inventors became true designers due to their extensive product knowledge and passion, so the commissioned industrial designer (a member of the research team) served as their "drawing hand." (Figure 2).

Figure 2. The S-bike concept design. Left: 3D model next to the styling analog DWX 250 electric motorbike by E-Max. Middle: prototyping in the workshop. Right: testing in the field. Image credits: Nikita Klyusov, Nikolai Korgin

4.2.1 Outcomes

For the industry, the outcome is an adaptable model of the process for manufacturing marketable products for harsh environments, as demonstrated by a series of functional yet designer-touched ready-mades. The transition from "desktop design" to the real world is especially important in terms of understanding what happens in the real world. The "user as designer" strategy turned out to be hard to implement for both designers and users. On the one hand, it forced designers to put aside their creative egos and become smart tools in the hands of smart users. On the other hand, it caused users to undervalue the designer's contribution. In our case, the "designer-company" collaboration ended when both parties recognised their respective limitations. At the subsequent stage, the transformation of the prototype into a commercial product required more specific expertise: that of industrial engineers to complete the mould and that of graphic and media designers to create a memorable visual identity. As a result, the S-bike has recently been released under the name Snegir (a bullfinch bird in Russian) and is now freely available as of December 2022.

4.3 Students

Student engagement and participation constituted a distinct aspect that was neither immediately commercialisable nor merely speculative. Focusing on "their own circle," i.e., the community of motorcyclists, the makers' collective initially insisted on creating a product that resembled a motorcycle but was equipped with skis and a track; this was the primary vector for the development of the product's main design (Figure 2, left).

The driving experience of an electric snowmobile is unlike that of a motorcycle or an internal combustion engine (ICE)-powered snowmobile, and a driver's license is not required. So, the students started by coming up with ideas about how this unique experience, the potential of electric drive, and the needs and opportunities of the harsh operating environment could be joined together to shape an innovative transport vehicle.

The student experience of working with the prototype began with a 3D scanned model of the original physical structure (Figure 3, left). As students were 2,000 kilometres away from the workshop, the makers scanned and sent the original model for further digitalisation and refinement. This 3D model, however, neither conveyed the proportions and ergonomics nor the experience of riding such a vehicle. Thus, the students made a full-scale, low-fidelity prototype out of foam board (Figure 3, right).

Figure 3. Prototyping the prototype. Left: results of 3D scanning and modeling. Right: low fidelity tangible prototype. Image credits: Nikolai Korgin, Svetlana Usenyuk-Kravchuk

As part of the design concept development process, students proposed several ideas that diverged significantly from the original design. These included utilising the distinctive plasticity of sheet material, exploring symbolic imagery through silhouette, and combining the expressive and constructive potential of generative design (Figure 4).

Figure 4. Selection of students' proposals. Image credits: Ignat Evstafiev, Ekaterina Fomina

In between studio work, there were several short-term visits to the workshop facilities, as well as additional low fidelity prototyping on-site. At this point, would-be designers not only tested their ideas and concepts to get helpful, and sometimes sobering, feedback from real users and makers, but they also considered the exact manufacturing process and learned about its limits and possibilities. In the case of small-scale production by a user collective, there are certain nuances: for instance, not every component can be produced locally, and many components must be sourced from larger manufacturers.

4.3.1 Outcomes

Even though the makers' collective lacked prior experience working with design students and was unfamiliar with the specific goals and tasks of a traditional studio-based design education process, they were eventually inspired to engage with students and viewed it as an investment in their own future. Yet, the process of coordinating interests was rather difficult and required rebalancing between real-world needs, short-term marketing aims, and a long-term vision for all-season electric mobility and commercialising user innovations. All of the original stakeholders – both academics and users-makers – put the company's new priorities and goals into action through the design student competition they set up (Figure 5). In contrast to many other student design competitions, the prizes for this one focused on the product, the company, and, in a broader sense, developing place-based design solutions in line with the Arctic design approach. The prizes were a trip to the testing area on the Kola Peninsula and a funded one-month internship at E-Max.

Figure 5. Selected projects. Image credits: Kirill Mukaseev, Daria Samofeeva, Lee Lin'vei

5 CONCLUSIONS

This case revolves around a prototype creating multiple entanglements between user innovation communities [10], situated learning [11], and participatory and co-design [12]. Expanding on the latter, our main insight into coordination of interests is that collaborative design process – considered primarily horizontal and democratising – at a certain stage can (and should) become intrinsically non-democratic and hierarchical. When two (or more) stakeholders are teaming up based on their creative sovereignty, at some point, to sustain the development process they have to become consciously unequal: one agrees to sacrifice their interests (e.g., professional, financial), i.e., agrees to be ridden, and the other is ready to ride. This inequality, we argue, is of key importance for the project implementation and further capacitation of stakeholders, especially when their paths will diverge after all. In our case, there are multiple actors, each of whom is the creator of a work of personal significance — either turning a prototype into a product, doing research through the prototype, or learning design from the real-life context. We described stakeholders as being unequally placed in front of the prototype, and this inequality is exactly what makes them rock', i.e., moving along their own paths while taking into account individual limitations.

The above discussion has direct implications for design education. Collaboration with user innovators in the case study exposed design students to real-world challenges and constraints that they would not have encountered in the classroom. Also, as Markauskaite and Wrigley note, for design education to remain productive, it must embrace the growing disciplinary diversity and richness to truly push the knowledge boundaries [1, p. 140]. This necessitates not only increasing the number of participants with diverse knowledge and expertise involved in co-design projects but also educating and training individuals to recognise and respect the limits of their own professional field.

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PEDAGOGICAL IMPLICATIONS OF SERVICE DESIGN FOR INDUSTRIAL DESIGN EDUCATION: CURRENT CLAIMS AND FUTURE DIRECTIONS

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ABSTRACT
With the service sector's dominance in the world economy, we have witnessed the development of service design as an emerging field. Not only do design programmes offer courses on service design, but there are universities offering undergraduate and graduate programmes specific to this field. However, the professional development of service design and its alignment with other design disciplines is still in progress. With this perspective, we aim to take a snapshot of current service design offerings at the university level to discuss their impact on the future of industrial design education. We systematically analysed the courses and programmes of the first 50 design universities with design schools listed on QS World University Rankings by Subject 2022: Art & Design. There are 19 universities offering a total of 82 courses and 12 programmes related to service design. Service design courses and programmes are more common at the graduate level. The analysis of service design course descriptions shows that the skillset and knowledgebase identified by these programmes are not highly unique. Their pedagogical goals are aligned with delivering human-centred design, design research, design thinking, and design strategy content central to industrial design education. Further integration of service design in industrial design programmes might mean a decrease in the high-fidelity model-making capabilities of industrial design graduates and an increase in visualisation skills for the communication of systems. Every industrial design programme must assess and align service design based on existing course offerings with averting redundancies in a competitive resource environment.

Keywords: Service design, industrial design, design pedagogy, curriculum

1 INTRODUCTION
Today's economy has been increasingly defined by services rather than the other two economic sectors, industry and agriculture. In 2021, the service sector contributed 76.74% to the US's gross domestic product (GDP) and 65% to the EU's [9]. While the service sector is not new, its expansion to e-services increased its significance compared to other sectors in the digital era. This reality and the competition around better service offerings have impacted organisations' service approaches. For-profit and non-profit enterprises have been investing in the design of services to better serve the user/customer, business, and society [2]. This sectoral need led to the development of service design as a field and increased the number of jobs requiring service design expertise [8]. These positions are filled by designers from diverse backgrounds, including industrial designers [2].
The increasing service design job market for industrial designers has also initiated a transformation in industrial design education. Some design schools have restructured existing design programmes to offer service design courses, while others have launched programmes specific to service design. The professional development of service design and its educational alignment with other design disciplines have been discussed for some time. Sleeswijk Visser and Stappers [5] discussed how the similarities between the "mindset, methods, and tools" of industrial design and service design helped the Delft University of Technology to incorporate service design courses into the industrial design engineering curriculum rather than offering service design as a separate area of study. On the contrary, two universities, one in Europe (Laurea University of Applied Sciences) and one in the US (Savannah College of Art and Design), started master's programmes in service design as early in 2009 [2] as an expression of the unique expertise requirements for service designers.

Regardless of being integrated into existing design programmes or being offered as stand-alone programmes, the pedagogical developments in service design can be interpreted as the need to deliver a unique knowledgebase and skillset for service design to prepare graduates for sectoral needs better. In the service-dominant logic, services are co-produced between users (customers) and service providers [7]. Designers need to consider how an experience around a service evolves over time and space to fully capture the interactions around multiple stakeholders and various digital and physical touchpoints [3]. At the same time, they need to consider the societal and environmental impact of their service design decisions for the global wellbeing [1,4]. Such plurality and complexity warrant a system-level approach. This brings the efficient and effective communication of systems, especially in cross-disciplinary teams, as a major concern in service design. In contemporary service design practice, communication tools such as visualisation techniques and prototyping are central to the service design process [6].
The systems mindset, methods, and tools in service design practice are familiar to the ones applied in the industrial design discipline [5]. This brings a question about integrating service design content into the industrial design curriculum. For service design to flourish sustainably within the higher education ecosystem, it is essential to understand the current state of the pedagogical offerings. Our paper provides an important first step to filling this knowledge gap by providing a snapshot of the service design offerings in higher education.

2 METHOD

To sketch the current state of service design education, we systematically analysed existing courses and programmes specific to service design offered by design schools worldwide. To do so, we consulted QS World University Rankings [10], a highly reliable international university ranking. We explored the service design courses and programmes offered by the first 50 universities' design programmes listed on QS World University Rankings by "Subject 2022: Art & Design."
We followed two strategies to extract the service design courses and programmes. First, we conducted a keyword search with the term *service design* (without quotation marks) on the official website of each university. We searched for information on courses or programmes in the results. We also explored the websites specific to each university's design schools and analysed the curriculums of the programmes offered in these schools to define courses. Second, we conducted keyword searches on google with the university name in quotation marks followed by *service + design* as well as the university name in quotation marks followed by the following terms: modules, curriculum, schedule, "course catalogue," "courses offered," "course offerings," "course list," "classes offered," and "class offerings." This second search strategy allowed us to access course catalogues for the universities that share them publicly. In these course catalogues, we searched for the courses with the term *service* in the course title. We specifically did not search with "service design" as our initial trials showed that there are service design courses that do not use this term in their title but use service alone.
We limited our search to schools of design and undergraduate and graduate programmes, but not masterclasses, online short courses, MOOC courses, or certificates. We only searched for the most current course catalogues available; we did not do a retrospective search (which was also not a feasible approach). We did not include the courses and programmes from other schools, such as business (e.g., Aalto University Master of Business Administration in Service Design) and architecture (e.g., Building Services course offered by Pratt Institute), as our primary focus is the implications of service design on industrial design curriculum. On the other hand, we included all courses in design schools where industrial design programmes are a part, as industrial design students have a higher chance of taking these courses as electives.
We collected data on the university name, school/college, department/programme, course name, instruction level (undergraduate, graduate), course description, and country information for the courses along with data on the university name, school/college, programme name, overview/description, programme type (undergraduate, graduate), degree granted, total credits, and country information for the programmes. Course descriptions and programme overviews/descriptions were analysed using the R statistical computing language. We implemented topic models using LDA (Latent Dirichlet Allocation) algorithm to cluster the courses according to topics and cosine similarity measures to examine the extent of similarity between course descriptions. We only report quantitative results for course descriptions because of space limitations, noting that programme descriptions show a similar trend.

We do not claim that our dataset is comprehensive enough to depict the whole reality around service design education. For example, we are aware of other programmes (e.g., the Service Design Strategies and Innovations (SDSI) programme that is a joint effort of the University of Lapland, Art Academy of Latvia, and Estonian Academy of Arts) that did not make it into our dataset because of the universities not being in the first 50 of QS ranking. We limited our analysis to the first 50 universities on QS ranking as we aimed to get a snapshot of the phenomenon to have an informed discussion on the impact of service design on industrial design education.

3 FINDINGS

Out of 50 universities, 28 were not offering any courses or programmes specific to service design during our study. We also had three other universities (Central Academy of Fine Arts (CAFA), Universidad Nacional Autónoma de México (UNAM), and Tongji University) for which either the official website was not working, or there was no English course and programme descriptions available.

3.1 Dataset overview

In our dataset, there are 19 universities offering a total of 82 courses and 12 programmes related to service design. Savannah College of Art and Design is the university with the highest number of courses (N=18) related to service design. This can be expected as it is also the university with the highest number of programmes in service design (one undergraduate and two graduate programmes).
There are seven universities offering programmes in service design. Service design programmes are more common at the graduate level (Table 1) than undergraduate level, and the UK is the country with the most service design graduate programmes in our dataset.

Table 1. Distribution of programmes across education levels and countries

Level	Country	# of Programmes	Total
Undergraduate	Hong Kong	1	3
	UK	1	
	USA	1	
Graduate	Hong Kong	1	9
	Italy	1	
	UK	5	
	USA	2	

On course level (Table 2), 52 courses are graduate courses, whereas there are 20 undergraduate courses. Ten courses are listed both at the undergraduate and graduate levels. The USA has the largest representation in the dataset, as 34 courses are from this country.

Table 2. Distribution of courses across education levels and countries

Level	Country	# of Courses	Total
Undergraduate	Australia	1	20
	Finland	4	
	Hong Kong	1	
	Netherlands	2	
	Switzerland	1	
	UK	1	
	USA	10	
Undergraduate and Graduate	USA	10	10
Graduate	Australia	9	52
	Finland	4	
	Hong Kong	6	
	Italy	6	
	Japan	2	
	Netherlands	2	
	Sweden	1	
	UK	8	
	USA	14	

Within our dataset, while 34 of the courses are offered by programmes specific to service design, 49 are offered by existing programmes (e.g., industrial design, interaction design, design strategy) at schools of design. This indicates the trend towards integrating service design into existing design curriculums.

3.2 Analysis of course descriptions

Of 82 courses in our dataset, 12 did not have course descriptions. For the remaining 70 course descriptions, Table 3 shows the frequency of tokenized words (features) used 15 times or more.

Table 3. Frequency of words that appear 15 times or more in course descriptions

Word	N	Word	N	Word	N
method	36	social	26	explore	20
develop	34	understand	26	context	19
system	33	research	25	complex	18
product	33	concept	24	solutions	17
experience	32	model	24	use	17
process	32	people	24	value	17
interaction	32	innovation	23	designers	17
tools	30	approach	23	innovative	16
business	29	sustainable	23	create	16
practice	28	user	21	technology	15

In course descriptions, the communication and analysis of services as "systems" and the complexity of the systems thinking approach are highlighted more frequently than other aspects of service design. This systems approach comes from the "sense making of complexity and organisational and networked relationships" (Aalto University, Designing for Services course). The emphasis on the systems is also followed by a reference to "interaction" to indicate a difference between service and system. Services are theorised as systems that involve user interaction. Therefore, it is not surprising to see a focus on human-centeredness in service design course descriptions with references to "experience," "user," and "people." However, the service design course descriptions also emphasise how they differ from any other design field, for which human-centeredness is paramount, by combining human-centeredness with other aspects, most importantly, with "business" and "social." The significance of "social" in service design is also represented by the words "public" (N=13) and "society" (N=8) in course descriptions.

The analysis of word frequencies also conveys the attention given to service design practice by the introduction of "methods" and "tools" in courses. Another important aspect to highlight is that the course descriptions do not only name specific methods (e.g., visualisation, co-creation) and tools (e.g., blueprint) to utilise in the process, but some also describe "design," "design thinking," and "design process" as tools to handle the complexity of services. The programme description of the Glasgow School of Art's Design Innovation and Service Design is an example of this: "At The Innovation School, Service Design is taught as a means of applying design processes to complex problems, combining artifacts and interactions to produce services that exist, unfold and evolve in both space and time."

The qualitative analysis of course descriptions also indicates that the courses aim to differentiate between being digital or physical oriented. Some courses try to combine both. These differences are partly because of the programmes that are offering the courses. While courses in communication design address the significance of digital interactions for services as touchpoints, course descriptions from industrial design programmes also add products as the main point of interaction.

One last point to highlight is the focus on the collaborative nature of service design. Course descriptions specifically address two types of collaborations. One is the value of cross-disciplinary collaboration and teamwork. The other is the utilisation of co-creation and co-design with service providers and users in the service design process.

The topic models in Table 4 show the patterns and relationships in course descriptions. Topic 1 is about the value of service design and what it brings to the table by emphasising how it differentiates from business-oriented service development. Topic 2 illustrates the content of the courses and what they deliver. Topic 3 is mostly about what is designed, especially with a human-centred approach to services. Lastly, topic 4 exemplifies the focus of service design and how this focus is different from other design practices.

Table 4. LDA topic models of course descriptions

Topic 1	Topic 2	Topic 3	Topic 4
people	methods	interaction	business
system	develop	product	model
opportunities	experience	user	sustainable
practice	process	different	system
use	social	technology	product
create	research	making	value
communicate	concept	creation	explore
explore	tools	people	challenges
interaction	understand	digital	stakeholders
ideas	innovation	first	strategic

As a last step, we also analysed how the courses are clustered. Figure 1 shows that the courses are grouped into four based on their descriptions. Two course descriptions from Chiba University (only the same, one sentence in both courses), one from the University of Technology Sydney, one from the University of the Arts London and one from Loughborough University were outliers and were taken out. The course descriptions with pink mainly address the relationships (e.g., among people, things) and inclusiveness (e.g., all stakeholders) that must be considered in service design. In this sense, these courses emphasise how the designers' focus should shift from singular (e.g., product, end-user) to plural (e.g., interactions, systems) during design. The common aspects of the course descriptions in orange have the objective of communicating and teaching human-centred methods and tools that are important for service design practice. The courses in purple highlight the service design process and communication with visualisation and storytelling. The last cluster in blue groups courses that describe services' complexity and system attributes. They bring the business and management aspects; assess and measure future service solutions. It is also important to note that the courses on product-service systems do not cluster in a different group. This might be interpreted as an overlap between service design and product-service systems course contents.

Figure 1. Course clusters based on their descriptions

4 IMPLICATIONS OF SERVICE DESIGN FOR INDUSTRIAL DESIGN EDUCATION

Given the significance of the service sector in today's economy, we expected to see a more comprehensive implementation of service design in higher education. Out of 50 universities, there were only 19 universities offering service design courses and/or programmes. This can be interpreted as a lack of understanding of the importance of service design in many universities and design programmes. Design schools are slow in addressing sectoral needs.

Service design courses and programmes are more common at the graduate than undergraduate level. However, more undergraduates have also been hired as service designers [2]. This can also be interpreted as a need to further implement service design competencies and skillsets at the undergraduate level.

The analysis of service design course descriptions demonstrates two main issues. First, some core offerings highlighted in service design course descriptions, such as human-centeredness, co-creation, and systems thinking, are not new to industrial design. These core offerings mostly overlap with the pedagogical goals of delivering human-centred design, design research, design thinking, and design strategy content in industrial design education. On the other hand, courses on service design also indicate a transformation in design education in general and industrial design education in specific. The sheer number of service design courses offered by existing design programmes is a good proxy for the integration of service design. At the same time, we do not observe a change in total course numbers or credits of industrial design programmes. This can be interpreted as the changing nature of industrial design education.

Based on our data, one of the core changes is the increasing importance given to system visualisation. However, the same cannot be said for the making aspect of design. While service prototyping is introduced as a tool in courses, this differs from the high-fidelity model-making common in industrial design education. Thus, further integration of service design in industrial design programmes might mean a decrease in the high-fidelity model-making capabilities of industrial design graduates.

In addition to a pronounced emphasis on business and user needs, one of the core aspects of service design is its focus on society and the public good. This focus expands the practice of industrial design beyond the commercial sector. This might be interpreted as a need to further include theoretical courses on social issues. There has always been an interest in social issues in industrial design. While this might be true, there has never been a coherent framework to address these problems.

Integrating service design into industrial design education further highlights design as a medium for multiple stakeholders to communicate and interact. Some service design course descriptions exemplify how visualisation techniques can become tools for co-creation. Hence, it is important to define and effectively communicate the designer's role in the ever-changing design landscapes to students through clear learning objectives.

Our study communicates the significance of service design in the industrial design curriculum. Our findings also illustrate possible redundancies in industrial design curriculum (especially on design research, human-centred design process, and design thinking) if the service design is hastily integrated into industrial design education without in-depth analysis. Every industrial design programme must assess and align service design based on existing course offerings with averting redundancies in a competitive resource environment. It is also important to reflect on students' experiences regarding service design course offerings, which our study comes short of addressing given our data.

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A STUDY OF CONSIDERATION FOR IMPROVING USER EXPERIENCE OF PORTABLE TOILETS IN THE POST-PANDEMIC ERA

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ABSTRACT
Portable toilets, also known as porta-potties, are a common solution for outdoor events, construction sites, and other places with limited access to toilets. However, hygiene concerns such as bad smells and physical contact have led to negative user experiences, resulting in a reluctance to use them. Primary research conducted in Hong Kong, Taiwan, and China found that many users avoid using them unless necessary, with an average rating of 1.6/5. Despite this, the global demand for portable toilets has increased due to the COVID-19 pandemic. A recent study estimated that the portable toilet market will increase from $12.61 billion in 2021 to $20.43 billion by 2028. This suggests that current designs of portable toilets may not consider post-pandemic user behaviours, as they were catered to pre-COVID-19 circumstances. To address these issues, this paper aims to provide a set of design considerations for toilet-related products. The redesign of the interior and exterior features of portable toilets should consider manufacturing, transportation, cleaning, and usage processes. By enhancing the user experience, the goal is to provide everyone with a wonderful toilet experience. This paper provides a valuable resource for academics and designers to refer to when designing toilet-related products.

Keywords: Portable toilet, user experience, post pandemic, innovative design

1 INTRODUCTION
"I want to use the toilet really badly, but there are only portable toilets here". Portable toilets have been around for decades. Some people believe it is a 'lifesaver' product, yet others consider it a "portal to hell". The unsatisfactory user experience has led to an unfavourable impression of portable toilets among the public. Moreover, since the COVID-19 outbreak, public health awareness has significantly increased. Portable toilets, a place with higher chances of potential breeding grounds for germs and viruses, have prevented people from using them during and after the pandemic. This paper aims to explore the challenges associated with the portable toilet user experience, hoping to increase the acceptability and usability of portable toilets during post-pandemic times.

2 BACKGROUNDS

2.1 The necessity of portable toilets
Portable toilets have been in use for almost 60 years since their invention. They are commonly utilized in urban areas with high population density and high demand for toilets within a short timeframe. While in rural areas, they are considered an effective solution for toilet demands due to the scarcity of water and electricity resources. According to the United Nations, World Toilet Day acknowledges the importance of toilets and highlights the issue of inadequate access to safe toilets for billions of people globally. Portable toilets are a vital part of the solution in providing improved sanitation facilities for those in need. In addition, Sustainable Development Goal 6.2 highlights that portable toilets are essential in achieving the 2030 objective of providing universal access to proper sanitation and hygiene, especially in developing countries where access to public toilets is limited (UN, 2022).
Portable toilets provide benefits not only to humans but also to the environment. The portable toilet industry has significantly impacted the environment and natural resources conservation. Globally, it helps save up to 473 million litres of fresh water daily with thousands of litres of fuel, making it a "green

product" with its materials and functional characteristics (Safe T Fresh, 2023). There is a significant growth in global portable toilet demand. The global portable toilet market was worth USD 11.85 billion in 2020 and is projected to grow to USD 20.43 billion by 2028. The COVID-19 pandemic positively impacted demand for portable toilets across all regions (Market Research Report, 2020). Portable toilets are versatile and flexible, making them ideal for use in construction and manufacturing sites without access to a continuous water supply. The demand for standard and customized self-contained portable restrooms are increasing in construction projects, manufacturing factories, and other commercial or public places.

2.2 Post-pandemic user behaviour change

During the COVID-19 pandemic, public and personal sanitation have become significantly more important to the general public, as the level of sanitation directly affects the public's health. However, during the post-pandemic periods, there is a change in user behaviour for public area usage. The psychological and emotional impact and consequences have influenced the way people interact with hygiene-related public facilities, which include portable toilets.

Despite the positive impacts that portable toilets have brought to society and the environment, many people find their user experience unsatisfactory and are generally unwilling to use them unless necessary. This phenomenon is seen more severely in the post-pandemic era, with a noticeable change in user behaviour towards portable toilets. Many people are hesitant to use the facilities due to cleanliness and hygiene concerns, which the demand for a more user-friendly and user experience-based portable toilet is needed. With the limited portable toilet variety in the market, design improvements and innovations are required to provide a wider range of options to cater the diverse needs. Therefore, this paper is expected to further investigate the user behaviour changes toward portable toilets by collecting and analysing relevant data, given the limited information currently available on this topic.

3 RESEARCH METHODS

Surveys and interviews with portable toilet users can provide valuable information on their experience, preferences, and suggestions for improvement. This could include questions about cleanliness, odour, ventilation, and other factors that affect the user experience. Based on preliminary research, user satisfaction and usability with portable toilets can be improved through design. To further understand the necessary form and function of portable toilet components to be most effective for user experience, primary research in the form of surveys and interviews was conducted via online methods.

207 surveys were collected mainly focused on individuals who have used portable toilets in the past, which are mainly in China, Hong Kong, and Taiwan. Questions from different categories, such as design preferences, cleanliness concerns, and accessibility features, were made into multiple-choice questions for easier and more specified responses. 12 interviews were conducted, ages ranging from 21 to 65, with a mix of frequent and occasional portable toilet users. The interview questions were focused on understanding the user experience, including common pain points and desired improvements. Questions were open-ended to allow users to express their ideas and opinions freely, with a focus on stimulating innovative ideas that were not thought of during the survey.

4 RESULTS

According to the survey findings, there is a clear indication of the low frequency of portable toilet usage, with 61.7% using it once per few years, followed by 19.6% using it once per year. The overall experience was bad (43.9%) with neutral (35.5%) and very bad (17.8%). The usage frequency of portable toilets is most influenced by cleanliness (65.4%) and smell (21.5%). Regular cleaning is necessary to increase hygiene and reduce unpleasant odours. Although the design features may not directly impact these factors, they can influence user behaviour and promote the care and preservation of the facilities. By asking users about the most difficult and unsatisfying aspects of using portable toilets, it can be determined which facilities require redesigning to enhance user experience. Respondents reported that flushing the toilet, washing hands, and using the toilet was equally difficult. However, when asked which process was most unsatisfactory, using the toilet was the most common response, highlighting the need for toilet improvements. The overall scoring for current portable toilets is 1.6/5. The factors of space, cleanliness, smell, appearance, and brightness are rated, and the results indicate that smell and cleanliness have negative experiences, while appearance is the least controversial. Understanding these user feedback trends can influence the design criteria for the design process.

According to interview results, the design pain points outcomes require basic and reflective improvements to enhance the user experience. Basic requirements focus on the practical functionality of internal facilities, while reflective requirements focus on the sense of cleanliness and security during usage, including surface height and material. At a visceral level, users of portable toilets rely on their senses of sight, hearing, smell, and touch to gather information about the environment. The appearance of the portable toilet has a significant impact on users' behaviour, as it is their first impression of the product. At the emotional level, users' feelings and experiences are strongly influenced by the tasks they perform in the portable toilet. Research shows that there is a "W" shaped emotional response curve, with users feeling the most satisfied when leaving the toilet and the least satisfied when encountering poor hygiene conditions at the beginning of their experience (as shown in figure 1).

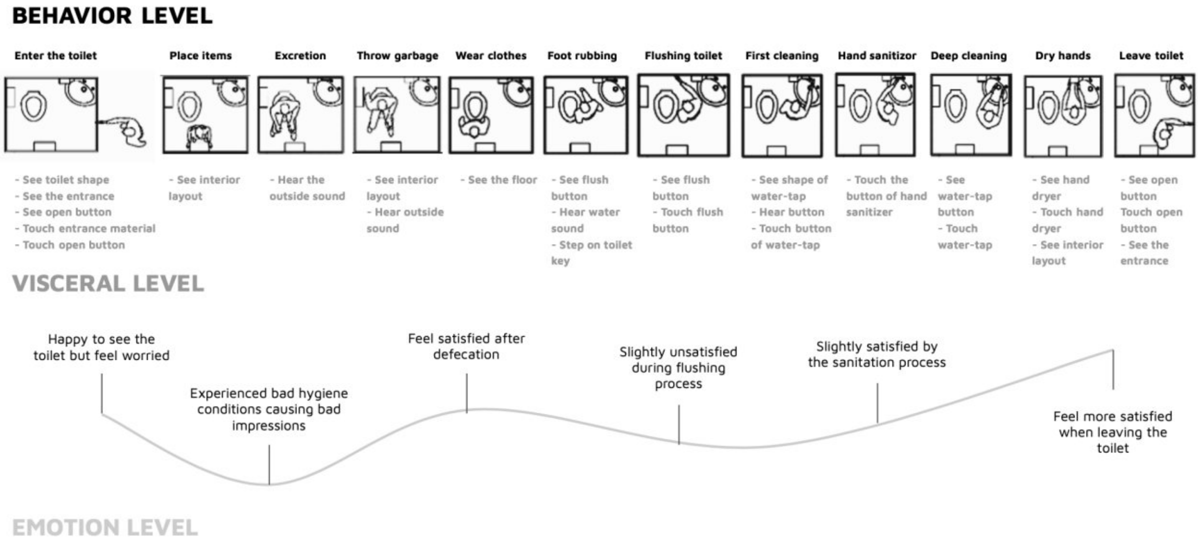

Figure 1. Behaviour, visceral, and emotional level change

The user journey map identifies pain points at different stages of portable toilet use. At the early stage, users may have difficulty finding and identifying available toilets. During usage, dirty surroundings and insufficient space cause hygiene concerns and discomfort. The interior and exterior designs may also feel unstable and insecure. After usage, users may feel rushed and experience psychological distress (as shown in figure 2).

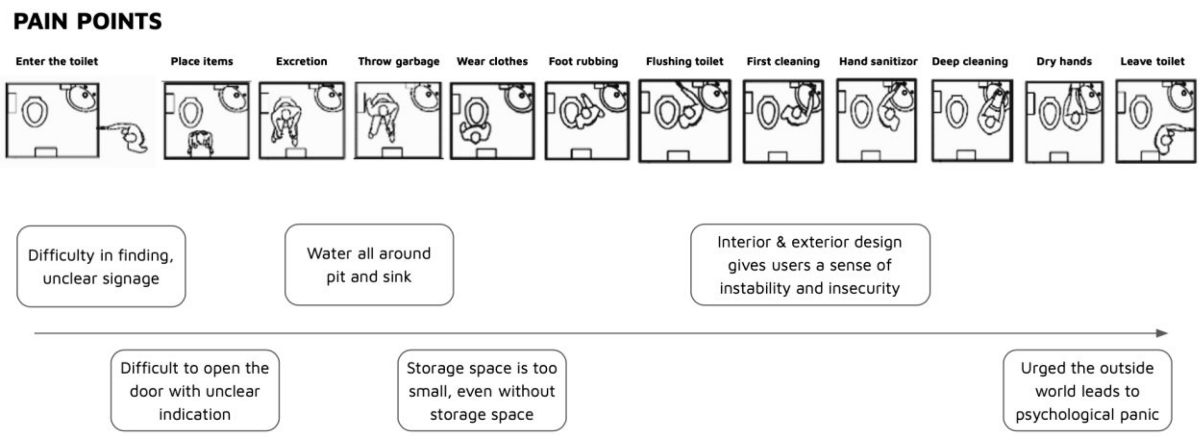

Figure 2. Pain points throughout the process

To further develop the design criteria for the portable toilet concept, brief market research was conducted to identify areas for improvement in current products. The purpose was to identify similarities and differences between these products and to integrate desirable features into a new portable toilet design (as shown in figure 3).

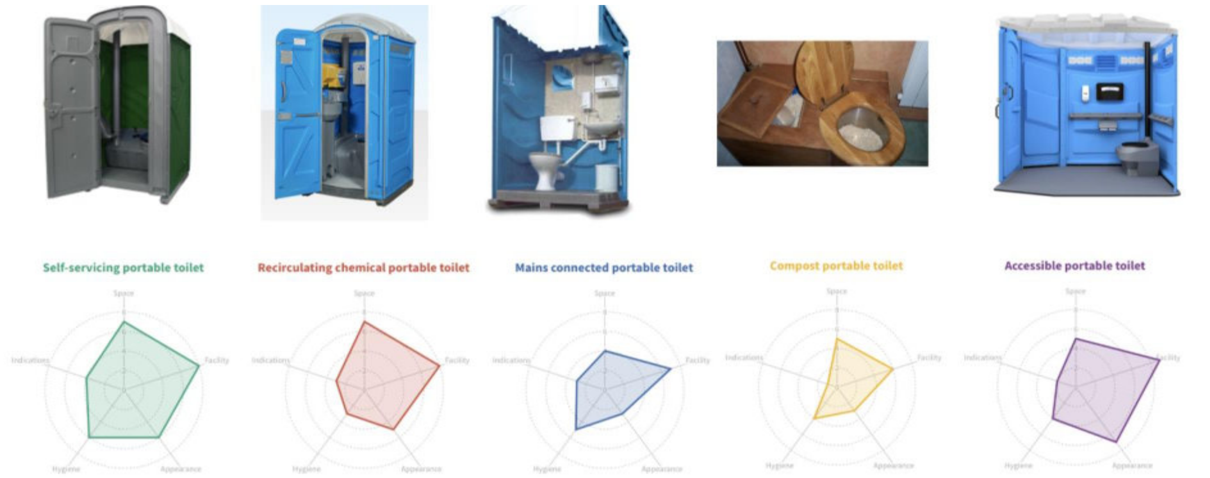

Figure 3. Existing portable toilets marketing comparison

Self-servicing portable toilet: This type of portable toilet is designed for easy and convenient cleaning and maintenance. It typically features a waste tank that can be easily removed and emptied by the user, eliminating the need for professional cleaning services. However, the capacity of the waste tank may be limited, making this option less suitable for high-traffic locations. Recirculating chemical portable toilet: This type of portable toilet uses a chemical solution to break down waste and neutralize odours. The solution is recirculated to minimize water usage, making this option more environmentally friendly than traditional portable toilets. However, users may find the chemical smell unpleasant, and the tanks require periodic pumping and professional cleaning.

Mains-connected portable toilet: This type of portable toilet is connected to a mains water supply and sewage system, making it similar to traditional restroom facilities in terms of functionality and convenience. This option is well-suited for long-term use in a fixed location but may not be practical for temporary events or remote locations. Composed portable toilet: This type of portable toilet uses a composting process to break down waste and convert it into nutrient-rich compost material. This option is environmentally friendly, as it eliminates the need for chemical solutions and reduces water usage. However, the composting process requires a certain amount of time to complete, making this option less suitable for high-traffic locations.

Accessible portable toilet: This type of portable toilet is designed to meet the needs of individuals with disabilities or mobility issues. It typically features a larger interior space, grab bars, and other accessibility features to ensure user safety and comfort. However, this option may be more expensive and less widely available than other types of portable toilets. Overall, the choice of portable toilets will depend on the specific needs and constraints of the location and user population. Factors such as usage frequency, environmental impact, and accessibility requirements will influence the selection of the most appropriate option.

5 CONCEPT DESIGN DISCUSSIONS

Based on the research findings, four key design criteria have been identified to enhance user experience and promote sustainability. These include a contactless experience to address users' concerns about physical contact, improved ventilation and odour control, easy cleaning and maintenance through interior and exterior design improvements and a self-sustaining solution that minimizes energy consumption and environmental impact. The final portable toilet design consists of various components, including a toilet, urinal, water sink, water tank, light, solar panel, and rotatable doors.

To enhance the user experience and enable a contactless toilet experience, a weight-actuated sliding door can be installed on the portable toilet. This means that the door will automatically open and close based on the weight of the user, eliminating the need to touch the door handle. Additionally, a footstep mechanism can be used for flushing or dispensing water, eliminating the need to touch any buttons or handles. Striped walls would be added to the exterior of the portable toilet to improve ventilation. This technique, known as architectural ventilation, uses natural winds to increase airflow and reduce odours. Additionally, keeping the inside of the toilet as dry as possible, can help reduce odours and prevent bacteria growth.

To make the portable toilet easier to clean and maintain, blind spots can be reduced by designing the interior with smooth curves and eliminating any corners or crevices that can trap dirt or bacteria. The textured floor can be replaced with a non-slip material for easier cleaning. Additionally, the exterior of the toilet would be designed with smooth curves and minimal crevices to make cleaning and maintenance easier.

Figure 4. Prototypes of the portable toilet design

Figure 5. Final portable toilet design

To reduce energy usage and make the portable toilet more environmentally friendly, a light-transmitting ceiling would be installed to allow for natural light during the day. To reduce the electricity needed at night, solar panels would be installed to provide lighting at night. This allows a self-sustaining portable toilet solution that can be used in remote locations without access to traditional power sources. These features can help improve the user experience, reduce the spread of germs, enhance ventilation and smell, make cleaning and maintenance easier, and reduce energy usage. They can be incorporated into existing portable toilet designs or used to create new, innovative solutions for portable sanitation (refer to figure 4 and 5).

6 CONCLUSIONS

In conclusion, portable toilets are essential for providing proper sanitation facilities for those in need and contribute to environmental conservation. However, the negative user experience and cleanliness concerns have resulted in a lower frequency of use, particularly during the post-pandemic period. To increase the acceptability and usability of portable toilets, design improvements, and innovations are needed. Our primary research, including surveys and interviews, indicates that cleanliness, smell, and physical contact are the most significant factors influencing portable toilet usage frequency, and redesign is necessary to increase hygiene and reduce unpleasant odours. Moreover, by incorporating design features that promote care and preservation of the facilities, user behaviour towards portable toilets can be positively influenced. These findings enabled an in-depth development of a user-friendly and innovative portable toilet redesign, to further improve user experience and promote sustainable solutions. As this paper aims to examine design considerations for toilet-related products, its goal is to provide a comprehensive set of considerations that can be referenced by others for academic purposes when designing such products.

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SUSTAINABLE DEVELOPMENT WITH WOOD MATERIALS AND DYNAMIC REPAIR

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ABSTRACT
This paper focuses on design processes, dynamic repair, and sustainable development with the reuse of wood materials. The project is based on a case study in product design conducted by primary school pedagogy students in arts and crafts range from about 20-30 years of age. The content of the education at Oslo Metropolitan University (OsloMet) for design, arts, and crafts is based on what graduate teachers are going to teach in primary school. The teaching students were selected as participants because they should carry out a work requirement and the design project would help their practice as a graduate teacher. The subject design, art and crafts is an optional course in the Norwegian primary school teachers' education. In terms of methodology, the examination builds on research-by-design and design process the where the practical aesthetic work with the materials is the deciding factor. Design process in this learning case is driven by a redesign process owned by the student. They were asked to design a +lamp made of wood and recycled material. They then examined the resources they needed to research the topic, thereby acquiring the requisite knowledge. Dynamic repair shows how material consciousness defines the design process from a sustainable perspective.

Keywords: Sustainable development, wood, redesign, dynamic repair and design process

1 INTRODUCTION: DYNAMIC REPAIR IN DESIGN EDUCATION

The research question is how dynamic repair, sustainable development and design methods are suitable for teaching themes related to different perspectives on reuse with wood materials.
Dynamic repair: The simplest way to make a repair is to fix what´s wrong. This called a static repair. "a dynamic repair will change the object`s current form or function once it is reassembled." [1]. The dynamic repair may invite new tools for working with objects.
I have clarified the curriculum goals for primary school. My students, in the subject of arts and crafts, learn about the process of design-method and other subjects related to "dynamic reparation". Sustainable development: Arts and crafts must qualify the student to take care of education for sustainable development as an interdisciplinary topic. In Arts and crafts, students must have knowledge of, and skills in reuse didactics. Material knowledge and craftsmanship are seen in a sustainable perspective. The education will provide research-based knowledge. The students are trained how to take action towards sustainable development. As in; climate, environment and competence to support pupils in their learning. This includes attitudes and actions towards sustainability. The students in Arts and Craft subject must have some knowledge and skills as a craftsman to be able to work with the concept of reuse-didactics. Knowledge about materials and craftsmanship are seen in a sustainable perspective. General competence in in primary and jr. high school: Explaining how the choice of materials, working methods and themes contribute to reuse, maintenance and consideration for the environment. The student should use the Design process as a tool in their processes. [2]. Students themselves get practice in standing in a creative process from idea development to finished product. The processes involving the reuse of products. The design process uses the following phases: Idea, analysis, further development, reduction and easement.[2]. The case exemplifies how design teaching can be executed in the education of primary school teachers with sustainability.
This paper describes a specific design task, including redesign and dynamic repair, performed by teacher students. They were asked to design a lamp made of wood and recycled material. With the guidance of a subject teacher educator, teacher students identified their own issues and questions. They then examined the resources they needed to research the topic, thereby acquiring the requisite knowledge.

Dynamic repair shows how material consciousness defines the design process from a sustainable perspective.

2 METHOD; A REUSE DESIGN PROCESS

The methods used in this study to address the research question were collecting data from a practical implementation of a reuse design process with written reflections, in Art and Crafts for teacher students at the Faculty of Education and International Studies, at OsloMet. The method also includes observation of the practical work. Students achieve a basic education that will equip them to teach design process in primary and lower secondary schools. Examines examples from a qualitative approach—research-by-design. Sevaldson presents a definition of *experimental practice*: 'The practice is experimentally changed and modified to explore and evolve concrete enquiries, research questions or effects' [3:28]. In this context, its research through the ethnological research method of participant observation [4:248-261], [5]. Research-by-design is used as exploration through practical creative work with materials in the design process, where one's own observations in an educational setting and the experiences of the students in the process also work as part of this exploration. Research-by-design is then implied in aesthetic terms. [3]. The method is used to explore the students' engagement in material consciousness and their experiences with the exploratory working method in the redesign process. In this context, it is interesting to note that Bresler emphasises that empathy, execution, and sensibility are qualities that are directly relevant to the research. [6], [7]. According to Schön, reflection is silent and unconscious; therefore, it is difficult for the outside world to see when reflection is present [8]. This reflection involves a dialogue between the hand, the head, and experience through the sensory apparatus. The design project is based on Richard Sennett's [9:120] use of the term 'engaged material consciousness', which is material consciousness that initiates a conscious, craft-based effort to achieve good quality work. This work is dependent on a curiosity about the materials at hand. Research shows that how we learn about global challenges also affects the competencies we develop [10:16]. Amongst their many other responsibilities, primary school teachers are also obliged to lay the foundation of knowledge for future engineers and product designers as well as for those who collaborate with them or who will utilise what they design.

3 THE STUDENT PROJECT

Based on a review of 25 log documents of students' design processes:
It has been possible to document some reoccurring findings. The students submitted a folder where they showed their process from beginning to end. They should also answer the following questions of their reflection. What significance does it have for you that you collected wooden materials and lamp parts initially? In what ways has this design assignment made you aware (or not) of dynamic repair and redesign for a sustainable future? How do you think it is to work with a practical approach to the concept of sustainability? How does your view of understanding sustainability change during this task? What part of your design works for you? What could you have done differently? Do you agree that research shows that theory about sustainability in itself is not enough, people must work practically to gain deeper and lifelong knowledge of a sustainable future? Answer yes or no.
Teaching is intended to activate students-in-practice and theory so that they develop knowledge, skills, and attitudes that are central to understanding and acting to achieve knowledge of sustainable development. Included in the redesign process of developing and creating, there were aesthetic occurrences, trust, freedom, surprises, and ups and downs. Knowledge so gained through redesign projects is more readily retained because it has been acquired by experience and in relation to a real problem. Product design illustrates the profound, though often hidden, consequences that design decisions and processes have on the total human experience. The research results describe how it affects the way the students think in a redesign process. Students should develop skills that are central to learning a skill and living for a more sustainable world.
The design task was performed in a primary school teaching course and had an environmentally conscious 'reuse' profile.
When the students work exploratively, they will gain experience with creativity, reflective and communicating aspects of research [7:76]. The example discusses points out essential details that have made themselves visible in the execution of the task: dynamic repair and engaged material consciousness for a sustainable future. The dynamic repair design task was to redesign a lamp with wood as the primary material. An old lamp was used as the jumping off point for designing a new one by using old wood

scraps chosen from boxes of leftovers. What are presented here are materials that are a source of inspiration to develop students' critical and creative abilities. Show how a teacher educator can support students' learning through a balance of structure, playroom and how this promotes the students' learning process.

4 DYNAMIC REPAIR AND REUSE EXPERIENCES

The assignment: Dynamic repair and redesign of a lamp is a sustainable field where there are many sources of knowledge to critically assess the task, assess new ways of joining parts, evaluate new looks, and take into consideration the different types of information that arise in the process.

According to Lenz Taguchi and Sjøbu, 'Physical objects and artefacts can be understood as part of a performative acting production of power and change which stands in active relation to other physical objects and people' [11:14].

Therefore, how these recycled materials feel and are experienced affects how the student works with the object and what choices he or she makes along the way; an interaction between the student and the material is created. Furthermore, one can say that all objects that surround people affect what is being learned. In the lamp project, the chosen objects are wooden materials from the leftover boxes and old lamps, which were combined to redesign a new lamp.

Learning takes place amidst the interaction amongst the students, teacher, tools, techniques, and materials. Therefore, the teacher educator should, in design projects such as this, make use of the potentials that exist in spaces, objects, tools, reused materials, and other materials. The students were given a guided reflection related to personal experiences with individual processes, learning and science to become more aware of how this affects their teaching.

Idea: First phase is to engage the students and get them curious about the topic to be explored.

Together with the student, the teacher will come up with reflection questions.

Here are some student questions:

'How can I make a table lamp/reading lamp that is characterised by a Scandinavian style?'

'How can I make a minimalist lamp that gives a lot of light and has an open solution?'

'A form of exploration of rhythm and repetition using different compositions of equal or three different parts.' 'How can I make a lamp by joining an old coat hanger, plank from a resting box and a new lampshade?

Activities in this ide phase can include showing examples of sustainable design projects, engaging the desire to achieve quality, and focussing on showing good design and craftsmanship.

Motivation and interest are important factors for learning outcomes, and the ide phase is central to students' further learning and should always be the start of a topic.

Learning activity refers to both physical activity and cognitive learning [12].

Analysis: A student reflects on motivation in his log: 'High degree of freedom made me extra motivated. In addition to finding the approach to sustainability, repair and redesign, time-consuming and exciting, and as future teachers, we have a responsibility to focus on incorporating this perspective into teaching. Self-determination, including virtually all of my fellow students, was motivating in itself. This led to increased ownership of the substance to be taught, which may both be motivating and increase understanding.'

There should be a goal of creating new and lasting products that the students can be proud of and that do not create new waste that is thrown away immediately once the teaching is done. The students work on making their own mind maps, materials collection, and stream of ideas in addition to asking questions, and they make pictures, sketches, drawings, and trials of three-dimensional cardboard models as well as work in the wood workshop at school or in learning demonstrations to learn how to use machines, tools, and techniques.

Further development: This phase gives students the opportunity to explore a problem through practical and theoretical work. The students themselves bring in data to elucidate the issue to be explored. Data can be collected from students' own explorations in the form of model testing so they can become familiar with materials, tools, and materials testing. Students must really explore the things they have gathered to see new opportunities with these. Student comment: I created mood boards and models to illuminate the issue to be explored. I experienced getting to know materials and tools by examining the wood parts and using the things I've collected to see new opportunities. I gathered knowledge through practical testing'. Further development brings together knowledge through practical testing.

Alternatively, students can gather other sources, such as theories or online resources, that inspire the process and can be collected and displayed in, for example, a mood board.
Production of product: In this phase, students will begin to process and build knowledge based on the information they have gathered about the topic.
With materials they have collected from leftover boxes and materials they have brought from home; they complete their lamp. Some use materials from recycling stations when designing their finished product. Central to the design are design and function. They gain basic experience with dynamic repair.
Assessment: The goal is for the students to build on their knowledge and draw conclusions so that they can make the knowledge their own and, thus, use it in other contexts. Here, the students can present their findings to other students through presentations, exhibitions, etc. In this way, they can practice giving a reasoned answer to the question they initially asked.

4.1 Static repair and dynamic repair

One student said:
`Through this task, we will create a sustainable lamp. This means that it should be a good craft so that it can last a long time and not just be thrown away when the project is finished.
This is an important thought to take with you to school as well. It is therefore important to talk to the pupils about this, so that the pupils are not just left with the thought that you make more rubbish out of rubbish (recycling).
- In the process we will also work with light and shadow, what is the purpose of the lamp, should it give a cosy atmosphere, be a ceiling lamp or an office lamp?
- Dynamic repair means changing something with the lamp - creating a new expression. In addition to using various techniques, such as sawing, planning, tapping, etc.`
This paper deal with the exploring and explaining phases and dynamic repair, because they have been proven through design process method to have a major impact on students' understanding of the process with a redesign product.

Figure 1. Some products

Figure 1 shows student's work product. There should be an interaction between open phases in the work where the students make their own experiences and structured phases where the students are guided towards the learning goals. Experiences with repairs became directly relevant to the students who took part in the project.
As one student said, 'The plugs were refurbished to join the subjects with such sliding that it is also possible to interchange them again. I said the area to the shelf with a jigsaw on the subject where the work drawing was signed. I felt a bit so that the edges became more correct, and then I wrote off the other topic and said it. I soaked the outside with a brushing machine. It took a lot of time to file the area where the shelf should enter. This is probably the hardest part on the lamp to get nice. I used two boards fastened with forces to not round the corners of the file. I used the same principle when I was going to brush in the hole for the light bulb. I drilled two equal holes in two plates that I attached to the force. The plates were harder than the oak, so I could not brush down the edges of the lamp. Then, I used a slab of sandpaper 60 to brush down the chips and notch inside the hole for the light bulb.'

The students had different assumptions. Those with a lower degree of knowledge were most unsafe in dealing with tools and techniques, and those with good knowledge had the highest degree of reflection of diversity and possibilities with tools and techniques. In order to understand and act for more sustainable development, students need to experience the world in reality, not just through theory [10]. Several of the students made different attempts at joining the exploration phase. The students processed and built knowledge based on the information they had gathered on the topic, which was joining techniques. The students took pictures of their trials and showed cardboard models and craft material samples. Images were put into a digital labelling folder, and the photos were supported by design, art, and craft reflections in the explain phase.

The design process created opportunities for testing different possibilities for dynamic repair as well as explaining and showing what ensures quality in the final product. The students reflected on this as a useful experience that strengthens product life compared to, for example, parts that are simply glued together. According to Sennett, 'The simplest way to make a repair is to take something apart, find and fix what's wrong, then restore the object to its former state. This could be called a static repair … A dynamic repair will change the object's current form or function once it is reassembled … the dynamic repair may invite new tools for working with objects' [9:200]. The redesign of the lamp is an example of this kind of dynamic repair; one adjusts, changes, and renews the object's original form. The redesign project challenged the students to reuse old wooden materials and lamps. Suitable tools, along with handling and touching the materials, became necessary to execute the dynamic repairs. A dialogue between the hand and the head [9], and a mutual acting production between things and people, was created [13].

To redesign a lamp and accomplish a dynamic repair required physical items, material objects, and tools. Several of the students acquired new material knowledge, and they expressed that it was inspiring to design their own lamp. This shows 'life experienced' and experiences through practical work.

The students themselves assessed what kind of potential they saw in the old lamps. To ensure high quality, the students were supposed to utilise one or several joining techniques, such as a mortise with wooden plugs, dowel joints, mortise and tendon, or finger joints. These joining techniques give strong and stable results and involve the necessity of being able to handle tools. Valuing diversity through work with materials became clear in the design process. The students experienced working their way into the materials in a more thorough way since they were relating to the properties of the wood, which leads to a greater material consciousness. One can see this material consciousness as a bodily experience—the act of sawing at a right angle, how one holds the plane, how hard one has to press the chisel against the wood to achieve exactly the track one would like, or feeling how a wooden plug has to be in order to fit precisely when one is joining two pieces of wood together. Here, one can see the body as Merleau-Ponty [13] does: as experiencing, sensing, and acting.

Through the work of creating a lamp, one can say that the students' craft-based efforts in the design process show an engaged material consciousness, but one can also say that it is a bodily manifestation of material experience. The practical work with the materials increases the students' engagement, understanding and faced challenges, such as the following: 'How do I clear the finish' 'It was also much harder to work with the hard oak than what I had seen for me, decay before I know what I know today.' 'I discovered many better solutions along the way, so I feel better equipped today to continue working with oak.' 'I think oak is a beautiful wood of high quality, but I recognise, both economically and for woodworking purposes, that it may not be the best wood for school use.' This can be understood as a transformation between materials and material understanding; it is a metamorphosis in accordance with the clarification of terms given in the introduction [9]. The exploratory working method approach to recycled materials can give a lived experience, where the possibilities and limitations of wooden materials are experienced and the students achieve new knowledge about suitable tools to connect something new with something old. Dynamic repair shows the students working their way into the materials as a bodily manifestation of material experience, but one can also say that the students acquired personal material experience with dynamic repair, where the activation of the sensory apparatus is central. Assessment took place throughout the process. Thus, the students gained a deeper understanding of how actions and the use of dynamic repair affect the process and outcome. Thus, students gained action competence in relation to sustainable development in a redesign process.

5 CONCLUSIONS

The research question asked how dynamic repair, sustainable development and design methods are suitable for teaching themes related to different perspectives on reuse with wood materials. [1], [2]. Design process as methods release learning with reuse, quality, dynamic repair, reflection, and communication. The learning is relevant to developing a good product and is also important for connecting knowledge from other subjects to the product's development. The students connected redesign to, for example, compositional principles in the development of form so that they achieved the expression they wanted in the lamp and understand the design process better. They showed joy and motivation during the project, but also frustration. For some of the students it may have something to do with the weakness of the method. The method is used to explore the students' engagement in material consciousness and their experiences with the redesign process. Through qualitative research [6],[7], the students find both inner and outer relationships in the practice with the design process. The new thing and what makes this project successful in this study is the connection between the design process, dynamic repair and reuse project inspires students to learn for themselves, bringing a real research-orientated approach to the re-designing subject. Do you agree that research shows that theory about sustainability in itself is not enough, people must work practically to gain deeper and lifelong knowledge of a sustainable future? Answer yes or no. 100% answered yes. When the students mastered the craft and dynamic repair, they expressed joy at being able to produce a product they were pleased with. It is important throughout this entire process, supervision and time management all played an important role.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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TIME – AN ESSENTIAL FACTOR TO RE-DESIGN LECTURES OF 'GESTALT-THEORY' - SDG 4 IN EUROPE AND RE-WRITING ART AND DESIGN HISTORY

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ABSTRACT
European research resilience depends on the element of 'time' in contextualisation and interpretations of design historian phenomena. The key factors of co-habitation and co-designing outlined in this research study show the factor '**time'** to be one core element in permanently updating didactic approaches. Within the scientific circle of design historians and design theorists, as well as other teachers in the field of 'Gestalt-Theory', like art and design history, we have to consider the element of 'time' as a significant and highly influential factor, which has enormous consequences for the 'quality of education' –with reference to SDG No. 4 (by UN). We as teachers and researchers in one person, need more time to integrate new research findings into our lectures. We must not ignore that the daily routine of a teacher and researcher does not leave enough time to evaluate the innovative, new research findings of design historians, art historians and archaeologists of the last decade to re-design the scripts and media for teaching. To exemplify the generally accepted stance that generalizing theories always depend on the current state of research, this paper uses as an example the different interpretations of images in Augustan time. Depending on the scholar's time-bound approach the world of ancient icons and images has received astoundingly different interpretations over the years. Consequently, design theory and art theory have to refer to and also reflect the current findings of affiliated disciplines if we want to do our jobs properly.

Keywords: European research resilience, demanding time to re-design Gestalt-theory, design and art history in context, sustainable education through cross-disciplinary research

1 INTRODUCTION
As interdisciplinarity working researchers in creative and anthropologically relevant disciplines, and as teachers in those fields we are also responsible for a sustainable future [1]. This can be achieved through interdisciplinary teams around the globe, which work together with sufficient financial support. Having enough time is fundamental for a profound discussion of research findings, and for a profound evaluation which leaves sufficient space for creativity and for finding new sustainable solutions: The cultural and economic significance, so to say the resilient profit, by learning from *a permanently evaluated* history, and by transferring the benefit for future generations of experts, will be introduced in chapter one and retaken again in chapter three. Re-writing scripts and re-designing lectures and adapting teaching methods to new research findings in art history, archaeology and design history are relevant for the SDG No 4 [2] and this has enormous consequences for the competences of future experts and the structure of future societies – it is not only about forming elites [3].
Case studies in art history concerning Roman time will be analysed to show the antique circle of sculptures and media and how through them power was established, spread, and maintained. This will be outlined in chapter two. Case studies are integrated in the subjects of representative sculptures and of historical (dress) codes, represented by different media and product languages, 'media languages' – to find new interpretations and new contextualization within a historical approach. Comparing the 'reading' different media, from different perspectives will have beneficial effects on lectures in Gestalt theory. The case study of 'New images of Augustus – Power and media in Ancient Rome' [4], that was

showcased by an exhibition in 2022, and the new findings concerning media and materials in ancient time, reveal consequences in contextualisation, namely new interpretation in design and art theory. If we do not invest in permanently evaluating and redesigning lecture media (scripts) for our courses, in design history, textile-design history and art history, we do not do our jobs properly.
Chapter three elaborates the pedagogical and didactic profit for re-writing lectures of art history, design history and 'gestalt theory'. Supporting in that way SDG No 4 – Education and Quality – it will supply the young generation with confidence [5], in times of uncertainty. At the same time, the body involvement focusses on a new scientific aspect in art history, when art historians like Andreas Beyer stress the corporal, body-active influence in the oeuvre, by the artists themselves [6] for de-coding and interpretation of art objects. In a summarized assessment of research findings, the key factors of co-habitation and co-designing are outlined – **time** being one core element in permanently updating didactic and scientific approaches.

2 FROM IMAGES IN HISTORY (CONTEXTUALIZATION) TO LANGUAGES OF MEDIA – TIME IN CONTEXT TO ART AND (FASHION) DESIGN HISTORY

2.1 Pictures, views and 'possibility spaces' – and the power of images in history

When it comes to cultural imprints during childhood and when we face, the 'Zeitenwende', pictures, views and 'view axes' are essential not only for physical experiences, but for the 'looking back - creating forward process' in design. For creating and ideating art and design, didactic perspectives for a resilient future, the SDG No 4 – 'Education and Quality' by the UN is one of the core SDG for academic, industrial, and economic approaches. The permanent review of teaching methods and of scripts, and the adequate contextualization of knowledge has to be seen as an essential support for the building of a resilient future i.e., for global co-habitation. Thus, the sociologist Richard Sennett argues that it is about restoration of techniques and rituals to ideate new ones [7].
For human beings, for generations with different cultural views, and experiences of global co-habitation possibilities, continuously adapted learning methods will be beneficial for cultural integration and will have a geopolitical effect [8]. Today the gen Z uses digital media in many different ways. This was different in the 1990s, when mainly printed books were used and sometimes hand-written scripts and photocopies were handed out by the teacher who had collected the relevant research findings. Teaching material, whatever it may be, not only conveys knowledge, but it also creates 'possibility spaces' [9], - an essential element for the creative design process. Unfortunately, even today a number of scholars does not want to adopt an interdisciplinary view to teach art and design history. But some field studies and new archaeological research findings in the fields of Roman history, for examples, fortunately tell us a different story: there are in fact interdisciplinarity working European research teams with new approaches to the power and usage of communication media – i.e., via sculptures, coins and other essential iconological media to express a 'Zeitenwende' during the lifetime of Augustus and Livia. One example with noticeable consequences for cultural imprint and long-lasting European aesthetic evaluation, is the colouring of sculptures in ancient times. In the twentieth century schoolbooks for example used to teach that white marble sculptures, manifested the ideal of those times, an idea which had been strongly favoured by Johann Joachim Winckelmann [10].
Recent research findings, however, revealed a different view, a different 'Bildwerk' (Engl: pictural work): the application of five or six natural colours with the strong symbolic meaning of red and blue and yellow. 'The colourfulness contributed in an enormous way to the decoding and made details visible. In that way, colour did not only get an aesthetic value, but contributed as well to the semantic content of the sculpture' [11].

2.1.1 Emperor Augustus - a case study

Emperor Augustus marks a turning point in Roman history: the transition from the Republic to the Principate. As the first emperor (27 B.C. to A.D. 14), he not only wields immense power, but also makes use of new communication strategies. They encounter a society in which a new 'desire for the image' becomes a widespread phenomenon. A central aspect of ancient pictorial culture is the image boom that broke out under the first Roman emperor Augustus. Honorary statues, state reliefs and coins with the image of the emperor are present in a density unimaginable until then. In addition to the public-political

image culture, other themes, especially from the world of Bacchus or Venus, appear in the private context. Numerous supposedly specific Augustan pictorial themes, such as the classicist images of the Campana reliefs or the so-called Third Style of Roman mural painting, appear through re-dating as pre-Augustan inventions, which are merely taken up in Augustan times and therefore lose their specific political significance. The archaeological research on Augustus during the last decades has been summarized in three major, very different syntheses. In her book on ‘Augustus. Kunst und Leben in Rom um die Zeitenwende’ [12] by the year 1986, Erika Simon unfolds a rich scenery of art and culture. From this intellectual-historical perspective the emperor and the new state order appear primarily as a framework condition of the rich cultural development; the interactions between politics and culture are seen thematically rather than functionally. Decidedly political, on the other hand, is the approach of Paul Zanker [13], which derives its analytical power from the experiences of the 1968 movement and from there examines and questions the significance of public representation in architectural and pictorial works for the construction of political power. Here the power of images is seen in an emphatically functional sense, recognized as a political-visual manifestation and viewed in the power play between ruler and society. In the pictorial themes as in the artistic stylistic forms, a mental habitus is diagnosed that was perhaps more effective than the political institutions or the activities and fates of the political protagonists. Here a diametric contrast to the grim analysis of Ronald Syme is to be seen ultimately an opposition between looking at the individuals and social groups with their actions and destinies on the one hand, and at the ideological, mental, and emotional tendencies and conditions on the other.
This new view was presented in the Berlin exhibition Emperor Augustus and the Lost Republic in 1988 [14]. How short this actually political phase of research was, however, becomes clear in Karl Galinsky’s book [15], where certainly rightly the idea of a centrally controlled propaganda in literature and pictorial works as it had, however, only been represented by thoughtless epigones was objected to. A very broad cultural pluralism is sketched out, in which continuity and change of literary and pictorial forms, adaptation and experimentation appear to be combined in a harmonious postmodern painting.
The autocratic rule of Augustus and the accompanying transition from the republic to the imperial era represent a drastic break in Roman history. In the process, images played an unexpected role. A new desire for the image led to a new approach to media and changed the style in the various genres such as wall painting, sculpture, architecture or everyday objects. New clients were part of this upsurge – not only elites but society at large could participate in both commissioning and appreciating works of art – which ensured an unprecedented wealth of images in all places. A veritable copyist industry made large-scale use of newly developed marble quarries.
The exhibition New Images in the Age of Augustus. Power and Media in Ancient Rome, presented by the Bucerius Kunst Forum Hamburg (8.10.2022 - 15.1.2023), the first Augustus exhibition in Germany in 34 years presented the images and monuments of this period with 220 objects, including statues, portrait busts, reliefs, wall paintings, coins and ceramics. The exhibition illustrated the new approach to imagery during the Augustan Age in five chapters: Portraits of the Emperor and Empress; New narratives and memorable images; The new cityscape; New and old cult representations and Domestic imagery between tradition and innovation. In the first section of the show, pictorial innovations were displayed in the way in which the Emperor chose to portray his own likeness. Through likenesses in the form of portrait heads, busts, statues and coins, which circulated as never before throughout Rome and the provinces, the imperial house was able to communicate with the people via a variety of media. Augustus couched his self-portrayals in new narratives and memorable images representing the history of the city of Rome, the divine origins of his own family, his various successes and the generally triumphant tenor of his reign. These pictorial motifs were displayed on prominent new buildings, for example, and attracted attention throughout the empire. Augustus publicised important buildings and construction projects across the empire by reproducing them on coins. The new devotion to imagery in the early imperial period was particularly evident in the private sphere. Homes were adorned inside with murals and picture galleries in the third, or ornate, style, while affluent citizens decorated their gardens with sculptures as well as marble and bronze tripods and candelabras. Tableware was now also discovered as a new pictorial medium.

2.2 Livia’s and Augustus’s dress codes in the context of time – European research resilience for art and (fashion) design history

The cultural spirit of a nation is shown by its cultural behaviour, following traditional and historically significant and long-lasting rituals in repeating and remembering fundamental guidelines, the DNA of

culture is transferred to the next generation. It is our cultural code, identity and knowledge archive [16] that is represented within historical objects and by people and their dress codes, and that has always to be interpreted as embedded in its very own period of TIME. When we regard Augustus as a turning point in Roman history: the transition from the Republic to the Principate, we should also consider the significance and influence of certain media, used at that time, to spread the (political) influence of Livia – Augustus' wife and her ideas of dress codes for example. To teach textile and fashion history means conveying a notion of a certain cultural identity via semantic meanings and interpretations of designed objects and dress codes. In fashion theory, we speak of 'vestimentary codes' [17], a term coined by Roland Barthes in the middle of the twentieth century. This expression has also lately been used by art historian Andreas Beyer in the year 2022, to underline the 'possibility space' which allows artists to express and expose their identity with insignia of the time, for example those by Albrecht Dürer in the year 1498. Beyer speaks of a 'vestimentary shell' [18] that is very precisely demonstrated - by textiles and other details in the product language Albrecht Dürer used for self-exposing - with a great sociological significance - contextualization.
A closer look at ancient sculptures, in order to understand their historical, philosophical, and sociological *background*, shows what gestalt-theory (courses) aims at: With a student group in Textile Design, we analysed the product languages, and de-coded the form and design of the garment, shown on marble sculptures, for example the dress worn by Livia, the wife of Augustus, shown at the Hamburg exhibition in 2022. Elements like proportion, form, cut of the pleated rectangle piece of fibres, the drapery, the colour and surface are important and are to be put into the context of time: on the one hand in relation to ancient times, and their very own social and political background, and on the other hand, to draw valuable information from the literature of different periods. It makes great difference, whether we study the books about fashion history from the past, for example 1889 [19], or whether we use latest scientific research findings, as e. g. published in 2022 in the anthology that accompanied the exhibition mentioned above [20]. From the latest studies by art historians, archaeologists and other experts, we can learn that in the times of Augustan reign not only colour had a greater impact on the semantic meaning, than we had known before. Only some years ago these students had been taught different things - based on the literature of the 1990s. Also new terms, like 'hip coat' for example, would be coined to demonstrate the power of the Emperor in the 2022 exhibition, an accepted scholarly view in the second decade of the 21st century. That means, elements of product languages (colour) and elements of language terms (hip coat) with consequences for semantic meaning, provide us with a new view of those historical objects. Empress Livia, for example, after the death of Augustus, was allowed to drape her robe like the vesture of a priest: A defined drapery and body setting, which was understood by all citizens, but which was defined by Augustus and Livia. The Empress was the first woman in Rome to pioneer a certain style of how to represent a house. Augustus and his wife defined an image of the culture at that time with different media, in a serial production of sculptures, coins and other precious objects. By the way, Livia as a woman with power and influence is an interesting object of study, too, in case of the SDG No 5 – Gender and Equality, in the state of art of discussions about themes of sustainability.

2.3 Courage in re-writing art and design history

In all academic disciplines it is to us teachers, to register these new research findings and to integrate them into the courses and into our scripts of history. Touching the field of design, art history, anthropological views and archaeological knowledge are essential to create the future – by knowing history – as well design history, textile design and fashion design history in contexts. The disciplines design and design history stand in relationship to art history and anthropology that were formed (gestaltet) by archaeological phenomena. Fashion codes, or textile codes imprinted on coins – all of them are **media and means** by which Augustus communicated and conveyed **ideas**. All of them then were and still are used to produce 'meaning', significance and political dimension, as was shown in chapters 2.1 and 2.2. Barthes writes 'Thus the general value of all conversions of signs into reason can be understood well beyond the fashion system itself.' [21], beyond the medial system as a whole, could be argued today. Merit to 'new images of Augustus', to act with new, different media – icons in special – and materials in time, show consequences in a new interpretation and contextualization in design and art history – and Gestalt theory, that demands for re-writing art and design history, and the scripts in follow. It is obvious that we have to call for more time for interdisciplinary discussions and cross-cultural co-designing and researching in Europe; and to encourage teachers, not only to take their time but to show courage and see the need for re-designing their lectures, and to re-write their scripts in interdisciplinary art and design history.

3 DEMAND YOUR TIME AND FINANCIAL SUPPORT TO RE-DESIGN GESTALT-THEORY – FOR THE PURPOSE OF SDG NO. 4

3.1 Educational demands for re-writing design and art history - and scripts The meaning of education as the most important key for sustainable co-habitation

Do we need new teachers, new teaching material to reach the Sustainable Development Goals in Europe and around the world? Or do we simply and only need time and 'possibility spaces' to educate the future art and design / historian experts? To formulate key factors of co-habitant and co-designing with the help of re-designing the courses and scripts (media) of Gestalt-theory, time is one core element in updating art and design didactical approaches permanently. This paper names a phenomenon, which is only rarely discussed, although teachers everywhere complain about not having enough time for re-writing and updating their courses, and their scripts. The following list contains some claims which are self-evident issues in the pursuit of the SDG targets:

- Encouragement to call for extra time, not only for research studies but for re-writing gestalt-theory courses (from scripts to multidisciplinary conveying media)
- Co-research with all partners or stakeholders means co-habitation in integration.
- Knowledge contributed by other cultures helps to build knowledge-pools with holistic views.
- Re-valuation of analogue tactile techniques (to save craft knowledge) and education with new learning techniques.
- Respecting and communicating meanings, mediated by (art and design) historical objects, trains the competence of reflection of future problem solvers.
- Living research communities mean connected cross-disciplinary research to serve the SDGs and in consequence to secure our sustainable operational abilities.

When we argued in chapter 2.1., that 'the didactically arranged learning media not only convey knowledge, but also create 'possibility spaces', we have to consider the impact of art and design history courses as such: they train creative competences and the ability to think and reflect. The 'recipient' can only use media to gain knowledge as a 'complex problem solver' if: 'One complex combines a variation of identifications, pictures, within all each influencing imagines, and offers in that way a script, that instructs the individual […] to play.' (Pazzini) [22]. As our case studies showed, it needs sufficient time to re-design the teaching material as elements of a permanently evaluated curriculum.

3.2 Education – our greatest investment, asset and profit

European research resilience depends on the element of time in the contextualization and interpretation of historical phenomena. The element of 'time' as a significant factor, with consequences for the 'quality of education' – in relation to SDG No. 4 (by UN) is obvious. The call for more time to re-write scripts adapt them to new research findings, stands in close relationship to a lack of financial support. In an interdisciplinary and broader contextualization which reviews 'old' and 'new' expert literature, research in relation to physical experiences within field studies – in this case in Rome – today matter again as pedagogical and design didactical benefit for the students, pupils and experts. The integration and participation of students into new research findings early on, and their experiences with 3-dimensional objects, will have a great impact on knowledge building. In a phase of growing digitisation and after a period without physical contact - because of the Covid-19 pandemic, body involving aspects are essential for our future experts. They will develop necessary and complex competences, which we desperately need for a European learning, research resilience and for the economy as well.

This paper is addressed to and would like to encourage teachers, researchers and talented students to claim more time and money for international interdisciplinary research exchange. Needless to say, the results will have multiple effects. Additionally, this paper is addressed to academic institutions: to integrate people and experts of the future in interdisciplinary Gestalt-theoretical courses, that will as well be beneficial for the pre-courses at school – this is resilient. The key factors of co-habitation and co-designing are outlined – **time** being one core element in permanently updating didactic approaches. This paper talks about a phenomenon which is only rarely discussed, though teachers everywhere complain about not having enough time for re-writing their courses, and their scripts. This is closely related to not receiving sufficient financial support. And this will have an essential impact on SDG No. 4 - Quality and Education and will also have a great impact on many disciplines close to cultural education, like integration. Integration in challenging times with enormous geopolitical problems is an important issue and approach supporting SDG 4. Integration of people requires cultural education and cultural understanding of products, design codes and languages – that means ‘contextualization’ and educating future problem solvers whether as design historians or design theorists, art historians or scientists of fine arts or archaeology. The axes of views are important, and this brings us back to the beginning of this paper: Our cultural imprints and interdisciplinary learning, the employment of multi-sensual media of communication, they all invest into the future, by improving education.

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DESIGNING WITH VIRTUAL ENVIRONMENTS: EXPLORING OBJECT ATTACHMENT THROUGH DIGITAL INTERACTION

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ABSTRACT

The purpose of this master's study pilot research project is to develop a framework for evaluating object attachment in a digital space. The article examines product design development through a game studies lens, making use of cross-disciplinary references. It seeks to fill a research gap by investigating the effectiveness of digital user engagement with object attachment via the research question, 'How can digital interaction be utilized to evaluate object attachment?' The study investigates the usefulness of a virtual environment in assessing user attachment to objects in a digital space, through a prototype experience and personalized interviews. Notes and data from the play experience were triangulated with qualitative data from interviews, to provide an analysis of opinions on object attachment inside the designated virtual environment. The aim of this pilot research project is to prepare for further studies of novel, inventive, and alternative methodologies for investigating user opinions of designers' and engineers' works. The discussion elaborates on the flexibility for educators to apply other design theories to such a framework. Finally, the study will examine the benefits and applications of this preliminary framework for students and educators of product design in a sustainable and collaborative context.

Keywords: Prototype, framework, attachment, user interaction, virtual, sustainability, education

1 INTRODUCTION: DIGITAL INTERACTION AND OBJECT ATTACHMENT

Attachment is pivotal to product designers, as understanding how users become attached to a product will help designers develop emotional experiences with the product [1]. Designers have been utilising and experimenting with VR, games, and real-time experiences as the technology behind them have grown over time. User-object attachment has been a constant subject of multidisciplinary discourse, from psychologists to consumer researchers. The research question was inspired by recent studies on digital object attachment [2], emotional attachment to characters in games [3], and attachment to virtual possessions in games [4]. There has been little research on exploring the effectiveness of digital user interaction with object attachment. This study aims to investigate this missing link through the research question, '*How can digital interaction be used to evaluate object attachment?'* Exploring this framework would be beneficial research for the education sector to explore the efficacy of a game-based, real-time prototype. Game elements and virtual learning environments in education have grown in use over the years, as newer generations of students come into schools with preconceived knowledge on how to interact with the medium[5],[6]. This study helps enable students and teachers to evaluate user opinions on designs through an emergent method, in an under-represented lens within product design.

1.1 What makes the framework novel?

There has been an increasing trend of product design research heading into the realm of VR. Whilst VR is an effective and immersive tool, the proposed framework exists within a game's engine - a 'platform tool'[7] - rather than a specific medium of hardware. The game engine is malleable, and the framework proposed can be edited to suit a designer's or researcher's needs, including incorporating the use of VR. By developing this abstract framework within the platform tool, the framework becomes more accessible and affordable to both designers and users, shedding the need of specific or expensive hardware or increased technical knowledge. Game engines have also begun to be used - and proven to be effective - for early design ideation, such as lighting in the automotive industry [8]. The framework highlights the phenomenological experience of the user, and the design of the virtual environment through a gamified lens. Finally, the framework centres the user's *attachment* to a product, rather than focusing on how a user responds to a specific aesthetic quality, such as the recent study on product *form* design by Xing Lu and Suixian Yang[9].

2 GAME STUDIES: THE PLAYER EXPERIENCE

To enhance a game design perspective, this question is seen through the lens of game studies. One approach can be to explore retention mechanics in simulation games. Simulation games themselves offer a sandbox with little to no end goal, allowing the user to play and experiment as they desire [10]. These types of games, ones that offer the player interaction with key systems, yet with no enforced goal, allow players to express themselves fully and provide them with the widest variety of options [10]. By creating a non-linear digital environment for users to interact with, their experiences will differ per play-through, as will the perception of these experiences per player [11]. By acknowledging that each player may have a completely different experience within the open prototype, it can be a research aim to prepare data collection that would be constant. What interactions and mechanics will a player certainly perform, and how is it possible to track them?

2.1 Sustainable Innovation Through Digitization and Digitalization

An open-ended simulation could be considered as 'half-real' [12], incorporating a form of reality - the physical objects that the digital ones are based on. Utilising this framework could be more sustainable for designers developing physical-based products, particularly if those materials are expensive, pollutive or difficult to manufacture [13]. A digitized version could be prototyped and interacted with, allowing users to explore the product digitally, but with parameters that would simulate the physical world. This digital prototyping process can be more fast, iterative, and customizable than its physical counterpart - products can be edited in 3D modelling software or even within the game's engine in less time. This is becoming more frequent in select industries, even becoming a customer-facing service within certain fashion businesses [14]. The fact that this prototype can be replicated physically can showcase to students the effects of digitalisation. showcase how a digital framework can be more sustainable from a manufacturing, social, and iterative view.

3 METHODOLOGIES

3.1 Abstraction: Designing Objects And The Environment

'Digital objects' can be a broad term. Work has already been done in differentiating digital object types, [2] but for the sake of this prototype, the digital objects in this study was simulated physics shapes. The design of the environment can prompt the user to explore the physics and materials of the object, through various lighting scenarios and forms. The approach was to develop an abstract prototype, as this reduced costs and time - the prototype only took two days to create. An 'Abstract Prototyping' methodology allows one to examine how the framework may be developed and changed for the future, but it's also easier to present and evaluate key concepts[15]. This led the object designs to be simple primitive shapes, with different materials assigned to them, which reacted differently to the lighting in the environment.

3.2 Multimethod Research

Through using multimethod qualitative research [16], this pilot study conducted a usability test in the form of a digital prototype, followed by an in-depth interview. The prototype also collected a small amount of quantifiable data which then enabled the interviewer to ask customised questions. This method was chosen as the data sets could be easily triangulated to evaluate the effectiveness of the prototype framework. The research was conducted through a phenomenological lens, due to the concept of phenomenology, and the uniqueness of the player's experience being so intertwined [17]. Four users in total took part in the study, and their personal data was anonymised. Users were aged 22-31, with varying degrees of gameplay experience, yet all knew at least how to navigate in a digital, first-person environment.

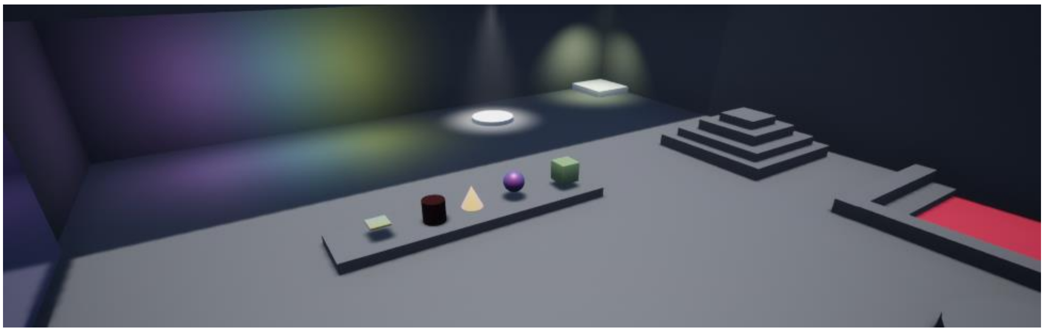

Figure 1. The layout of the prototype environment

3.2.1 Prototype Usability Test

First, the user played a prototype experience. The prototype was designed in Unreal Engine, and incorporated a sandbox-style playground, with a row of interactive objects in the centre [Figure 1]. These objects were able to simulate physics and responded when the player picked them up with the mouse button. They could be held, moved around and placed within the level. Before they began, each user was told that they must focus on and examine the objects in the space and do whatever actions they want to them. In Fig.1, there is a red zone; The users were told they could dispose of the objects if they would like to, and the objects would be removed from the level. They were finally told that this experience is a sandbox with no end goal. They were then free to play the experience. After they confirmed that they had examined each object comfortably, they could finish. Two sets of data were collected during this test - Observation notes made whilst users were playing the experience, and in-engine data collected afterwards. The in-engine data showed how many times users picked up each object, what time they spent in proximity to each object, and what areas of the level they spent the most time in.

3.2.2 In-depth Interview

During the interview, initial questions were asked to each user, starting with them ranking which objects they felt attached to, from most to least. After that, they were asked to elaborate on their reasons why. They were then asked about their thoughts on areas in the level, and then their thoughts on the amount of time they spent with each object. The small subset of quantifiable data from the play experience, combined with the notes made whilst the user was with the prototype, formed a background to ask more custom questions in the interview stage afterwards, such as, *'Why do you feel you spent the most time near this object/area?'* The interview data was triangulated with the two sets of usability test data to evaluate the user's attachment to the digital objects.

4 RESULTS

The abstract prototype software ran successfully with no errors for each participant. Each participant was observed examining the objects and the play space, and due to the non-linear design, were able to express themselves in various ways. Common themes were found amongst each participant during the usability test - each participant gave themselves a goal to perform in the sandbox. It ranged from building a structure, to placing objects into areas they felt belonged the most. Users tended to explore how the physics of the object interacted with the environment, yet that may not have been the most important factor for some when it came to ranking the objects they felt most attached to. When asked to rank how attached they are to the objects, each participant put the cylinder last, but for different reasons. Some said that they didn't like how it reacted with the environment, whilst others didn't like the colour of the material. Three out of four users ranked the cone as the item they're most attached to. When asked to elaborate, users had different reasons, ranging from they liked how the object moved when picking it up, to the colour of the object being their favourite. In every single case, the objects that the users spent the most time in proximity to was not their highest-ranked choice. When looking at data on how often users picked up each object, it did not correlate to the object that they were most attached to. However, participants tended to pick up the object they had ranked last the least. By asking customized questions, users stated that they appreciated different areas of the level according to their personal preference and if those areas helped enable their own set goal. For example, one user wanted to build a structure using all of the objects and chose to do that in the spotlight zone due to it having a podium and interesting lighting. Two users disposed of objects, with one user disposing of four out of the five objects during their play session. When the user was asked why they disposed of so many objects, they stated they wanted to see what would happen. Even when told that this digital environment was a sandbox, due to being an experienced gamer, they wondered if disposing of the objects would solve a puzzle or change the objects in some way. Each participant spent at least 3 minutes minimum in the virtual environment until they felt comfortable that they had examined each object.

5 DISCUSSIONS AND REFLECTIONS

5.1 Key Findings: object attachment through experiences in a digital sandbox

From the in-depth interviews and observations in usability tests, players developed their own non-linear methods of experimenting with the objects in the play space. Through their preferences, users tested the object using the mechanics of the environment, and the tools given to them. Although abstracted, users had enough elements to interact with the object through their preferred methods of observation. Players trended towards viewing the objects that they were most attached to through either a haptic or aesthetic lens - focusing on how the object looked, or how the object responded to their inputs. No objects made any audio output or were deformed when thrown. By providing users with agency in a digital sandbox, they were able to comfortably explore objects through their unique lens of player experience. Although they may have had different reasons for their rankings, participants' objects that they were most and least attached to were almost exact, with one deviation. The user's previous experience with gamified experiences influenced how they approached the task, with one user attempting to break the sandbox with the objects to 'find a hidden door'. Another user, who has less gameplay experience, tended to struggle picking the items up, and approached the examination with a more hands-off concept - by placing items where they felt they fit aesthetically in the environment, not considering the physics of the objects at all. The small amount of quantifiable data gathered was certainly helpful in questioning and exploring player choices, such as asking why they picked up an object so many times if it wasn't the one they were the most attached to. This has been noted by studies on product attachment - that just because a user engages with products and is positively stimulated by them, does not mean that they will become attached to them [1].

5.2 Using design tools for triangulation: Kansei Engineering

As the design of the virtual environment is abstracted, it is possible to apply various design tools such as Kansei engineering, for triangulation depending on what data we would like to adjust and gather. Kansei engineering is a process that aims to centre the targeted user's thoughts and feelings into the design of a product [18]. The process has an overlap with games design, as the core premise of designing games is requiring a user's interaction with a system, and focusing on how they respond to the product [19]. It is therefore possible to apply Kansei engineering to deconstruct user's thoughts and feelings and categorize them accordingly. Such a method was used by X. Liu and S. Yang when exploring product form with VR models [9], although in a more quantitative way. They created quick-form questionnaires after a user has reviewed a 3D model virtually and utilized that data as part of a Kansei engineering exploration. It is possible to explore a similar approach with the proposed pilot study, to gather qualitative data such as a user's thoughts and feelings during the process due to the gamified nature of the framework.

5.3 Promoting Global Cross-Disciplinary Collaboration In User-Focused Design

Broadly speaking, digitization is recognised to be very important in many countries. It offers ways that countries can collaborate with each other in a faster and easier fashion than they have previously [22]. Digital objects can be transferred faster and more sustainably than their physical counterparts, allowing global collaboration on digitized designs of their products. By utilizing a digital prototype, it is possible to promote a faster, easier and more sustainable method of collaborating. Students can be encouraged to work with other countries and disciplines as the framework can be edited to suit more specific needs, such as examining a user's attachment to a certain material of the object, or how the object responds audibly. The issue with digitalisation is that a baseline of equipment is needed to contribute, and marginalized regions may not be able to provide those specific needs. It may also be easier to find specific users to interact with the framework as the entire process can be performed digitally, with the researcher examining the gameplay through screen-sharing tools. Users would need specific equipment that allows the prototype to be played. This framework can promote environmental sustainability when collaborating, as it removes the needs for users, researchers or designers to travel geographically [23].

5.4 Educating Newer Generations

In regard to education, this form of methodology would be useful in showcasing how the gamification of usability tests lends a unique insight into object attachment. Students may want to examine this methodology due to its 'gamified' lens and would be able to easily grasp concepts due to their pre-conceived experience with a virtualised culture [20]. As game design can be a unique and emergent medium within product design, students may want to experiment with a different design lens than they are used to. However, due to the abstracted nature of the prototype, other design theories could be applied, such as Kansei engineering. Educators can showcase new, unique, and relevant product design processes that tackle rapid prototyping development and consumer-orientated innovation which are important for companies to produce [21].

5.5 Limitations

Whilst four participants felt like an adequate amount for such a qualitative pilot study, there wasn't a diverse range of age and previous gameplay experience. The one user that had less gameplay experience interacted in a radically different way from the others, as noted in the results. Previous game experience can have a large effect on how the user interacts with the object in a digital space, and this should be investigated within further studies. Utilizing quantitative data was very beneficial for asking in-depth interview questions, and whilst there wasn't a lot of correlation between the in-engine data and ranking of object attachment, this could be explored in a wider-scale study. Deploying and researching the use of emergent media such as game engines within prototyping and product design is under-represented, due to the multidisciplinary nature of games studies itself. Further research is needed on exploring product design through a game's studies lens. There is a lack of research measuring whether user attachment to a physical object and their digital counterparts are identical which should be explored in further studies, although it has been found that virtual products are more effective at communicating a product than text or image, inside VR, and viewing 3D models through a desktop [9], [21].

6 CONCLUSIONS

The findings from this study can influence methods of evaluating user object attachment, through a new, emergent and underrepresented lens. Each user's play experience with objects will be unique when presented in a non-linear digital environment. The findings show that users may set their own goals if presented with none, when given a task of examining objects. The study demonstrates that by using a game engine, (or other real-time digital environment) it is possible to measure effective parameters which would not be equally feasible in a physical space. This can help to open the field up for future quantitative studies or enable researchers to go more in-depth with their qualitative research. The data indicates that object attachment can be evaluated in a digital space, particularly when triangulating qualitative data. This framework has supplied an example of how it may be used in an educational context, by providing a new abstracted framework that designers can establish their products within. Educators can also explore and evaluate digital interaction with their students through this prototype, from a new perspective. They may also be able to apply product design methodologies and other design theories on top of the prototype to teach and discuss them in a new fashion. Additionally, the framework has showcased how it can be used to promote a more sustainable method of prototyping and researching object attachment. The findings of this paper suggest that developing a virtual environment for digital interaction can be transformative and customizable according to a designer's needs, and as this methodology was abstracted, it should be clearer how a designer can do so. The amount of varied data collected shows that placing players in a gamified digital prototype environment can be an effective way to measure object attachment, as users are encouraged to explore and play with designs. This pilot study on exploring a methodology through an underrepresented lens provided valuable new insight into the potential future of prototyping and evaluating object attachment.

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TOWARDS A BETTER HUMAN CENTRE DESIGN PRACTICE IN AN ACADEMIC CONTEXT

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ABSTRACT
This paper addresses potential challenges in executing human-centred design (HCD) in an academic environment, focusing on (i) lack of sensibility and empathy in ethnographic research, (ii) misinterpretation of qualitative data in solution design, and (iii) uncertainty in user implementation. The study aims to enhance HCD education and improve ergonomics and efficiency in Chinampas agriculture through social perspectives. It describes the implementation of HCD strategies with undergraduate design students using challenge-based learning, employing an ideal-contextual prototyping approach. Experts and professors provided diverse perspectives and guided students in sensibility, empathy, and data interpretation, resulting in multiple approaches for each design solution. The dual-prototyping approach facilitated the acquisition of competencies, leading to a working prototype with a potential positive impact. This educational model addresses HCD challenges and fosters the creation of high-impact artifacts.

Keywords: Human-centered design, regenerative agriculture, educational innovation, prototyping

1 INTRODUCTION: CHALLENGES WITH HUMAN-CENTRED DESIGN

Human-Centred Design (HCD) is a versatile yet structured method that has been adopted by the Design Department of Tecnologico de Monterrey to instruct innovation and product development. As stated by Holeman and Kane [1], the HCD approach is centred on the active engagement of users to enhance the comprehension of users' needs and task requirements. According to Mao et al. [2], this approach enables students to generate design solutions with an empathetic perspective. The incorporation of user involvement and empathy in HCD makes it a valuable technique for teaching design students how to develop products and services that accurately meet the needs of their target audience. Nevertheless, there are some challenges when implementing HCD in an ideal way. According to Vredenburg et al. [3], many practitioners fail to include actual users in their process, and when they do, practitioners may overlook user data and find it challenging to identify areas of opportunity when developing sensible solutions. If HCD can be difficult for regular practitioners, it can be argued that it can be even more challenging for design students in an undergraduate programme. In the last five years as education practitioners, we have learned that by deploying HCD in an undergraduate academic programme, teachers can face several challenges in achieving a viable design solution generated by the students. Through past experiences, we have identified three obstacles that contribute to these challenges. The first is a lack of sensibility and empathy during ethnographic research, which can be exacerbated by socio-economic inequality in the Tecnologico de Monterrey context, where most students belong to a higher socio-economic class. This inequality can lead to a belief in exclusivity and privilege among the upper classes [4], resulting in a lack of sensibility and empathy. To address this, it is essential to push students towards several ethnographic-driven field exercises to enhance empathy while identifying problems or areas of opportunity. The second is the potential for misinterpreting qualitative data during the design process. In HCD, qualitative data is collected through activities such as deep dives, shadowing, or co-creation; however, for this data to be helpful, it must be translated into meaningful insights through analysis [5]. This analysis is integral to the creative design process, but it can be difficult for inexperienced design students to gather unbiased data -due to a lack of understanding of both tacit and formative theories, which can make it challenging to distinguish relevant and valuable data from irrelevant information. To overcome this challenge, it is essential to encourage critical analysis and to provide students with the tools and knowledge necessary to gather unbiased data, as we will explain further, utilizing generative research tactics. The more rigorous the analysis, the better chance students have of gathering accurate data. The third challenge lies in ensuring user implementation of proposed solutions, as industry partners may view them as mere inspiration or lack the resources needed. Implementing product design in a Mexican context is challenging due to factors like a low innovation culture [6] and a lack of private investment in innovation [7]. Therefore, it is crucial that the solutions proposed in an academic project consider the capabilities and limitations of the industry partner to increase the likelihood of successful implementation. This paper presents a strategy to potentially minimize the challenges previously discussed in implementing HCD in an academic setting. In collaboration with industry partner Arca Tierra, these strategies were implemented with fourth-semester design students at the Tecnologico de Monterrey's Mexico City Campus. This study evaluates the effectiveness of strategies for addressing challenges in ethnographic research, including lack of sensibility and empathy, misinterpretation of qualitative data, and implementation issues. It offers valuable insights for educators and practitioners seeking to enhance their HCD practices in academia.

2 REGENERATIVE AGRICULTURE TOOLS, A CASE STUDY

Tec21 is a novel educational model at Tecnologico de Monterrey that focuses on developing assessable, real-world skills through a deep educational blueprint [8]. As one of the goals of Tec21 is to provide real-world experiences for students, a "formative partner" is brought in to present a real-life challenge for the students to design a solution for. The idea is that the formative partner will find practical value in the design solution generated during the semester.

The Design Department follows the Tec21 model, and in the fourth-semester design course, students are presented with their first long-term design project that lasts the entire semester. During that semester, students go through three consecutive five-week formative units that resemble the Discover/ Define/ Develop/ Deliver design framework. The first formative unit, "Creative Thinking and Process," deploys activities that encourage secondary and primary research, the outcome of which is a validated design brief. In the second formative unit, "Specification of Products and Services," students are encouraged to create a minimal viable product through a highly iterative prototyping process, the outcome of which is the documentation for production and a working high-resolution prototype. Lastly, the third formative unit, "Design and Innovation," focuses on showcasing their idea through an entrepreneurial engagement by further validating their prototype, creating a visual identity, and preparing a business pitch to be presented to the industry partner.

In February 2022, we implemented this model with 20 design students divided into six teams. Our formative partner was Arca Tierra, a company based in Xochimilco, Mexico, specializing in regenerative agriculture and working with local farmers and other local producers as a way to recover and preserve the chinampa [9]. The chinampa is an ancient agro-hydrological system developed by the Aztecs in Mexico City. It involves constructing rectangular plots of organic soil over shallow wetlands for agricultural use and is notable for its sustainability and preservation of pre-Hispanic design. Despite its long history, local producers still use chinampas today [10].

As the farmers working with Arca Tierra use basic, makeshift tools, the formative partner challenged the students to create ways to make the local agricultural process more efficient and enjoyable, which became the brief of the project.

2.1 Implementing HCD Research on a Tec21 Model Design Course

In the first unit of the creative thinking and process course, the focus was on HCD Research. During this unit, two potential challenges were identified and addressed. The first challenge was the lack of empathy and sensibility in solution generation, a common issue for the students´ socio-economic sector. To address this, students were encouraged to participate in several field trips and to use questioning techniques such as the five why method and deep-dive interviews.

The second challenge was the students' difficulty in understanding the difference between qualitative and quantitative research methods. To address this, a team of three professors, two of whom were experts in Design Strategy and HCD Research, provided tutoring and constantly reviewed and questioned the students' HCD tactics. The professors emphasized the importance of qualitative data collection techniques such as shadowing and deep-dive interviews and data analysis methods like clustering and problem statement insights.

Hanington [11] states that by using proactive generative research techniques, subjects of the research can project their thoughts, feelings and desires, and extract design elements that can be used to develop concepts closer to the needs of the users. The professors' guidance and support helped the students to better understand the value of qualitative research methods in HCD research.

To start applying the design strategies, an initial field trip was conducted to observe the regenerative agricultural process and gather ethnographic data through photography and video. The collected data was analyzed to identify three potential opportunity areas for product design. The professors emphasized the importance of linking tangible evidence to their hypothesis and validating the relevance of their concept through critical thinking and complementary field trips.

2.2 Implementing Ideation on a Tec21 Model Design Course

The ideation phase involved a combination of Dalton's five principles of effective insight definition [12] and Alquemist's Elements of Value [13] to understand better and differentiate the functional and emotional needs of the Arca Tierra workers. This approach helped the students become more empathetic, better understand the workers' needs, and generate more realistic design proposals.

Dalton's five principles allowed for the effective articulation and validation of the initial hypothesis, while the application of Alquemist's Elements of Value helped the students consider both functional and emotional aspects in their design proposals. This combination of methodologies facilitated a thorough and holistic approach to product design, ensuring the relevance and impact of the final design solutions.

A thorough understanding of the context was considered to address the third challenge of ensuring user adoption of the proposed solutions. As previously noted, Mexico presents difficulties deploying innovation practices in product design. This results in farmers and workers having to create their own tools, commonly referred to as "herramientas hechizas" (makeshift tools, which we will refer to below as "hechizo tools"), which are made from scraps and lack any certification from a manufacturer. These makeshift tools also have equivalents in the market that are certified and manufactured by recognized units with a quality system [14].

Commented [DGC1]: ¿Así se les dice a las herramientas? o se si sean también como "make-do" o "improvised tools"? Después las llamas makeshifts. Creo que es bueno fijarles un nombre y que asi se les mencione en todo el texto posterior a la primer mención.

Commented [JRdlOC2R1]: Justo busqué una referencia que define el termino "hechizo"

Commented [JRdlOC3R1]:

The use of "hechizo tools" by farmers and workers is driven by economic constraints and the unavailability of the specific tools needed for a task, making it a challenge for the design project. On the one hand, the students must be sensitive to the economic and infrastructure limitations of the users' living environment and avoid proposing solutions that require industrialized manufacturing techniques, such as injection molding or metal casting, which may not be feasible. On the other hand, fourth-semester industrial design students must acquire knowledge of these mass production processes; this presents a unique challenge in Challenge-Based Learning (CBL).

To address this conundrum, an approach inspired by speculative design was taken as this approach helps to question our current practice [15]. In the first formative unit, the professors encouraged the students to research not only the functional and emotional needs of the users but also their access to manufacturing processes, trades, and artisans. In the second formative unit, the students focused on generating solutions using a concept called *"Treasable Manufacturing"* [16], a speculative design tactic that encourages the design of a product as if it were made from standardized materials, and the manufacturing process was very traceable. This approach would allow the final user to utilize the result as a blueprint for replication.

In the third formative unit, instead of focusing on the pitch and visual identity of the project, the professors decided to take an "idealist" speculative design approach. The students were tasked with designing the "hechizo tool" as if it were designed by a global hardware company, requiring them to continue their research on industrial production processes and materials.

Overall, the approach balances the need to address the limitations faced by the final user and the need for the students to acquire foundational knowledge in industrial design.

3 RESULTS

The students formed six teams, applying User-Centred Design tactics to develop agricultural tools for chinampa farming. They gained insights into farmers' work processes, identified areas for improvement, and created prototypes for local replication and industrial production. The work process involved mud collection, transportation, flattening, grid tracing with a "cortadora" tool, seed placement, and transplanting. Each team developed Hechizo and Ideal prototypes (see Figure 1).

Figure 1. "Hechizo tools" Prototypes (above) and Ideal prototypes (below)

3.1 Land Plotter

These students developed two prototypes to improve the accuracy of tracing growing beds in chinampa agriculture. The first prototype featured a wooden square with a retractable reel, nylon thread, and a low-cost laser guide. It enabled farmers to mark and divide the terrain accurately using laser light and retractable thread. The second prototype was an ideal redesign with an injection-casted polypropylene enclosure, providing versatility for rural architecture and construction. These tools aimed to enhance bed tracing accuracy and efficiency in chinampa agriculture.

3.2 Support Stool

Another student group addressed the challenge of manually flattening growing beds using a wooden plank and bricks, which was unsafe and required multiple workers. They developed two prototypes: an optimized wooden stool for easy transport and a metal stool made of carbon steel sheet. The metal stool offered improved stability and mobility, ensuring safety during planting.

3.3 Soil Healer

One student group addressed the inefficiency of the mud-flattening process using a machete. They designed the "Soil Healer," a leaf-shaped tool with an extended handle to let the farmer flatten, patch, and heal the soil surface without bending down. The first prototype utilized a steel tube and tip, while the second prototype employed die-casting and plastic injection for crack repair in seedbeds. The aluminum sheet design featured a rib for strength, reinforced at the pressure point, and included a hinged lid for convenience.

3.4 Fork

The students recognized the need for improved ergonomics and mud displacement in the makeshift tool to trace the growing bed's grid. To address this, they created two prototypes. The first prototype was a metal steel tube and steel screed "fork" designed to prevent mud from sticking and enhance visibility and precision. The second prototype featured a redesigned tool made of galvanized steel and ash wood, utilizing die-cutting and plastic injection techniques. This version incorporated a mud cleaner, resulting in a dynamic and practical work process.

3.5 Soil Puncher

A group of students aimed to improve the efficiency of the hole-punching process for farmers by designing a new hand tool. The tool, consisting of a fork with three movable spikes, allows farmers to punch multiple holes at once, reducing the time and effort required and avoiding potential injury to their fingers. The first prototype was crafted from lathed aluminum, while the second utilized a combination of polypropylene, carbon steel, and aluminum for its construction.

3.6 Seed Dispenser

The students designed a seed dispenser to address the time-consuming and labor-intensive nature of planting seeds in chinampas. The dispenser aimed to reduce seeding time by 25% and improve agricultural efficiency. The first prototype utilized 3D printing and was donated to farmers in Arca

Tierra. The second prototype was designed for mass production using injection molding. This innovative solution enhanced ergonomics, minimized worker strain, and saved time in the seeding process.

4 CONCLUSIONS

In conclusion, the methodology of constant tutoring that focused on empathy, insight generation, and people values has generated new tools that are currently being used by the farmers of Arca Tierra. The first prototypes were donated to the community and received positive feedback from the leaders. The project was also awarded the "best of show" prize at the *Horizontes* exhibition[1] and winner at the *Diseña Mexico Awards*[2], showcasing the project's successful outcomes and highlighting the importance of integrating empathy, people values, and flexible educational models in design projects. This approach can contribute to developing more insightful, viable, and sustainable projects that effectively address real-world issues. The authors would like to acknowledge the financial support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in producing this work.

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TEACHING EMPATHETIC DESIGN THROUGH THE PEDAGOGY OF DISCOMFORT

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ABSTRACT
Students and novice designers, especially those just out of high school, have difficulties understanding the concept of empathy in the design process. In addition, they often confuse empathy with sympathy, and their design solutions show an element of condescension and stereotypical outcomes.
To address the above problem, we have employed two strategies; 1. Transformational teaching: to create a dynamic relationship between teachers, students and a shared body of knowledge to encourage learning and personal growth [1]. This was achieved through situated learning with teachers acting as intellectual coaches who guide as and when required. And 2. Pedagogy of discomfort, According to Boler [2], pedagogy of discomfort as a teaching practice aims at disorienting learners through unsettling their taken-for-granted assumptions; and, consequently, engaging them in 'collective witnessing', 'mutual exploration' and 'deliberate listening'. This was achieved by designing the learning context to engage students in an activity that is both surprising and requires them to un-anchor from their comfort zone.
This paper shares our experience using the strategies mentioned above to teach empathic design to novice designers. We discuss our findings around a case study, an interdisciplinary course comprising students from visual design, industrial design and nursing working together in a culturally diverse environment to solve a real-world problem based on ageing and dignity.

Keywords: Inclusive design, transformational learning, pedagogy of discomfort, empathetic design

1 INTRODUCTION
We observed novice designers, especially the young, have difficulties empathising with target groups significantly different from them in age, capabilities, culture and cognition. In addition, they often confuse empathy with sympathy, and their design solutions show an element of condescension.
Although we use tools like empathy suites as part of the user-centric design process, it often does not produce effective pedagogical outcomes mainly because students take the empathy suite exercise as an academic challenge to be overcome to complete course requirements rather than realising how it feels to be in that condition indefinitely.
As Nadan and Stark [3] noted. *"Learning about 'Others' brings with it the risk of over-generalization, as well as the risk of overlooking the intersectionality of different categories of difference… and other personal circumstances and attributes. This, in turn, can lead to stereotypical attitudes towards people and the tendency to ignore their unique needs and life stories…. Such an approach may promote the view of groups as natural, homogenous, static and detached from macro structures."* In other words, this is an antithesis to the inclusive design paradigm - Which is all about recognising diversity and designing to accommodate it.
To address the above problem, we have employed two strategies: the transformational teaching [1] and the pedagogy of discomfort [2]. The pedagogy of discomfort is an educational approach that challenges students' existing beliefs, assumptions, and comfort zones in order to encourage critical thinking. The transformational teaching approach was employed to create the necessary learning environment to foster intellectual and emotional discomfort as a means of encouraging students to confront and question their preconceived notions, biases, and limitations.
This paper shares our experience using the strategies mentioned above to teach empathic design to novice designers. We discuss our findings around a case study, an interdisciplinary course comprising students from visual design, industrial design and nursing working together in a culturally diverse

environment to solve a real-world problem based on ageing and dignity. Within this context, we view the disconnect between the user expectations and the user experience as a design opportunity, where a design intervention can resolve/solve a negative user experience.

2 EMPATHIES IN THE DESIGN PROCESS

The core steps in the iterative design thinking process are defining a problem, attempting a solution, and, if not satisfactory, going back to re-defining the problem, and it goes on (Figure 1). In the design thinking process, "problem definition" is strongly tied to "Empathy" as it allows exploring the nature of the problem and understanding the users' needs and aspirations [4]. Empathy serves as the driving force behind the innovative process in design. Koppen and Meinel [5] rightly noted that Dorothy [6] was among the early authors to explore the significant connection between design and empathy, introducing the term "empathic design". In her perspective, empathic design empowers companies to enhance their products by understanding and addressing customer needs that may not be readily apparent. It involves immersing oneself in the customers' own environments to identify opportunities for product refinements. Without empathy, the essence of good design is lost, as it is this empathetic connection that brings forth designs that truly resonate with people [7].

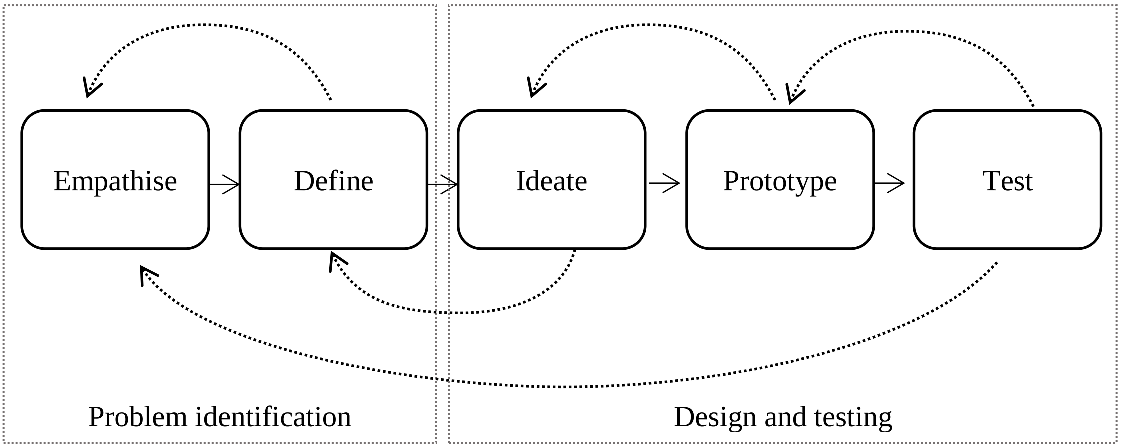

Figure 1. Design thinking process

Empathy is often confused with sympathy; although they are closely linked, they are not the same. Empathy involves understanding and sharing the emotions of others, often through personal experience or the ability to imagine their feelings genuinely. It’s the ability to understand and the ability to feel connected to the emotional experience of others without living it. Sympathy, on the other hand, involves acknowledging and showing concern for someone's situation without necessarily experiencing the same emotions.

The exploration of empathy remains fragmented, with various studies focusing on different aspects of this broad phenomenon. Moreover, research on empathy has progressed within distinct disciplines and separate research communities, leading to a lack of cohesive understanding [8]. Kouprie and Visser [9], based on how empathy has been discussed in design and psychology literature, proposed a framework to encourage empathic approaches in design practice. The framework consists of four phases (1) discovery, (2) immersion, (3) connection and (4) detachment. In the 'discovery’ phase, designers engage in activities that raise their interest and curiosity around the problem resulting in a motivation to explore and discover the user situation and experience. The second phase, ‘immersion,’ is the key phase where the designer immerses themselves in the environment of the users and experiences the user’s world from their perspective without being judgmental. The third phase, ‘connection,’ is closely related to the second; here, the designer brings in their own experiences in order to understand what the user feels and what it means to them. In the last phase, ‘detachment,’ the designer gets back into design mode and leverages an increased understanding of the user and the problem to generate ideas that better align with their needs.

3 TEACHING EMPATHY IN DESIGN

Teaching empathetic design requires the disruption of students' comfort zones and engaging them with end-users who may be marginalised or face different challenges than they do. They must develop the skills and resilience to face challenges by exposing themselves to uncomfortable situations. Such as designing projects that require one to work with diverse stakeholders, confront ethical dilemmas, or address sensitive issues to recognise their biases, assumptions, and limitations. They are encouraged to reflect critically on the impact of their design decisions and understand the broader implications of their work. Finally, supporting agency: Empathetic design can be a powerful tool for social change when designers are critically engaged with the social and ethical implications of their work.

When teaching the concept of empathy in design, it can be divided into three distinct components. In addition to mastering technical techniques, it requires a transformative shift in attitude and the adoption of a new mindset. To effectively teach empathy to young designers, it is crucial to push them outside their comfort zones and expose them to diverse experiences. This process enables them to develop a genuine sense of empathy towards users by breaking away from their familiar frame of reference and embracing new perspectives [10]. In this study, we are exploring the use of a transformational teaching approach and elements of pedagogy of discomfort to create the necessary environment to teach empathy to young novice designers effectively.

3.1 Pedagogy of Discomfort

According to Boler and Zembylas [11], the pedagogy of discomfort involves several key elements, including disruption of the status quo and challenging the dominant beliefs often taken for granted. It was achieved by creating a safe and respectful environment to encourage students to share their perspectives and engage in an open dialogue while ensuring that all students feel heard and respected.

Pedagogy of discomfort as a teaching practice aims at disorienting learners through unsettling their taken-for-granted assumptions; and, consequently, engaging them in 'collective witnessing,' 'mutual exploration' and 'deliberate listening.'

- Collective Witnessing: involves creating a space where students collectively witness and engage with uncomfortable or challenging experiences, narratives, or perspectives. It encourages students to acknowledge and confront social injustices, inequalities, and systemic issues together, fostering a sense of shared responsibility and collective action.
- Mutual Exploration: the importance of students engaging in dialogue, discussion, and exploration of diverse perspectives. It encourages students to actively listen to and learn from one another, valuing the exchange of ideas and experiences. Through this process, students can develop a deeper understanding of different viewpoints and challenge their own assumptions.
- Deliberate Listening: involves actively listening to others with openness and respect. By deliberately listening to others, students gain new insights, build empathy, and foster a sense of connection and understanding.
- Encouraging emotional dimensions of learning and creating opportunities for students to reflect on and share their emotional responses to difficult topics and issues. Fostering empathy by encouraging students to consider multiple perspectives and to develop a deeper understanding of the experiences and perspectives of those who are different from themselves.

These components of collective witnessing, mutual exploration, and deliberate listening work together to create an environment that promotes critical engagement, empathy, and transformative learning. They encourage students to confront discomfort, question dominant narratives, and develop a broader understanding of themselves and the world around them.

3.2 Transformational teaching

The transformational teaching approach creates a dynamic relationship between teachers, students and a shared body of knowledge to encourage learning and personal growth. To engage students in discomfort pedagogy, it is essential to establish a supportive and inclusive learning environment where students feel safe to express their thoughts, emotions, and discomfort without fear of judgment or reprisal to encourage critical thinking. This is achieved through situated learning with teachers acting as intellectual coaches who guide as and when required. Among others, basic principles of transformational teaching include constructive learning, where students actively engage in the discovery process and construct their own knowledge and understanding through active engagement with new information and experiences. And social constructivism, where learning is more impactful when it involves social interactions and collaborative learning in the construction of knowledge and understanding.

4 METHODOLOGIES

The primary aim of this exploratory study is to help understand if we can encourage students to employ empathy in their design practice by encouraging them to challenge preconceived design narratives using key elements of 'pedagogy of discomfort'[11].

4.1 Process

We have employed Kouprie and Visser [9] empathic framework to encourage empathic approaches in design practice. The framework consists of four phases (1) discovery, (2 & 3) Immersion and connection and (4) detachment. And we used a transformational teaching approach and elements of pedagogy of discomfort to operationalise the Kouprie and Visser [9] empathic framework.

- Discovery: we used the empathy suite, workshops on design for the aged and group discussions to encourage students to raise their curiosity and motivate them to engage with the fieldwork.
- (2 & 3) Immersion and connection: Students spend two days in old age homes supervised by care takers to observe and immerse themselves in understanding and feeling what the older people experience from their perspective. They also need to verbalise their experience as blog diaries to reminiscence and reflect on their experience.
- Detachment: Here, students break into small groups to use their understanding to design an intervention to address any problems they have identified during phase 3. The outcome of their design projects is presented as posters in an exhibition for feedback.

4.2 Participants

As part of a staff-led two-week study tour, Australian students majoring in design, media, and nursing travelled to Singapore to work with peers from Singapore, Taiwan, and Hong Kong. Students were from the year 3 Bachelor of Design (Visual and Industrial) course, ages between 22 and 26 years. They collaborated with residents of elder care facilities and community hospitals throughout Singapore as part of this study tour to co-design fresh ideas that benefit Singapore's ageing population. Students investigated issues related to ageing through a programme of design thinking workshops, site visits, ideation, and prototyping. They also collaborated with end users to co-create new services, technologies, and products based on their needs. The two-week study involved over 23 Nursing and 11 design students. We only used data from 11 design students for the purpose of this experiment.

4.3 Data

We have used two assessments of the study programme to measure the effectiveness of the process. The first assessment is a student learning experience diary/ blog, which they were asked to update throughout the study period, and the second is a poster presentation of their final design concept.

Student learning experience blogs were our main source to access the success of the teaching approach we tool. We were mainly looking at how they negotiated discomfort resulting from challenging situations and how they made sense of it in the context of their practice and Boler's pedagogy of discomfort's three key components of engagement: collective witnessing, mutual exploration, and deliberate listening. We also looked at if the learning was transformational or was it on the surface. Transformative learning involves an individual learning to think critically by questioning themselves about their beliefs, assumptions, and perspective that shape how they operate [12].

5 OBSERVATIONS AND RESULTS

Here we share a few snippets from students' blogs that summarise the outcome of the strategies employed. The quotes below are typical entries observed in students' reflective learning blogs.

> *"The visit has influenced my way of design thinking mainly from speaking directly to the residents and experiencing what they feel and how their daily lives are living at the centre. Being in their shoes really makes you start thinking about how life is truly so short, from the stories which were told dating back to when they were my age and being told that I am still so young…. The take aways from the visit would have to be personally experiencing life in a centre and how difficult it can be not being able to have control of your life in certain aspects, it's just so natural now to have complete control of life and I just find it difficult to image it otherwise. But from these visits to the*

homes and interacting with the residents on a one-on-one personal level has truly changed my thought process of life as an elder citizen."

The above example is something most of the student groups expressed in their blog. That we all age and that our current capabilities are not permanent and will change with time. It reflects the Pedagogy of discomfort elements of disorienting learners through unsettling their assumptions; and engaging them in 'collective witnessing,' 'mutual exploration' and 'deliberate listening.' This simple realisation itself worked wonders in how they were emotionally engaged with the design problem.

"Perhaps the most surprising thing about the visit was the number of elders who just wanted to talk to a new face in a world of normality. Many of them had very little English language, but thanks to some of the Singapore students being able to communicate for us, conversations flowed well."

This is one more realisation we have encountered often. That many older residents are more interested in the social interaction with the students than what they were offering them as design interventions. In fact, some of the groups were a bit lost as they realised they could not identify a concrete problem as they were just happy to spend time talking to students than sharing any compelling problems they were facing. Here again, students disrupted their preconceived ideas and explored design interventions outside of their comfort zone.

"However, I found out very quickly that my questions (prepared earlier in workshop) were not as applicable as I'd hoped…"

Here student group have prepared a bunch of questions and suggestions for elderly care home after the empathy workshop at the beginning of the tour. However, they realised that most of their ideas were already implemented by the organisation.

" From the discussion on the first day I did not realise that classes were already held (such as cooking and art) and that skills were already taught (from a government programme, but it was unclear if this was in the past or still continuing). They did not mind the idea of more group activities, but the people we spoke to already seemed satisfied with the activities. Other issues seemed more pressing and universal to the residents – like the small space….."

This visit influenced my thinking about the project in we have to be flexible in the design process, and the project should be something that could help people more universally, not just in this centre. One of the things that surprised me most about the visit was how similar aspects of the centre was to the centre my own Grandmother attends back home in Australia, and other aspects of elderly living. From the alarm system to the ever-present love of bingo, it was interesting to see how these things transcended different cultures. One of the other major take aways was how multicultural Singapore truly is…"

As can be seen, this group soon realised that preconceived ideas and suggestions might not be appropriate for the problem they were working on. And that they need to be flexible and more open to the needs of the end users.

Of course, we had a few groups who could not break away from their preconceived ideas about what older people need and were basically looking for a reason not to abandon them. The below reflection clearly demonstrates their intent.

.... She told us of family and tradition and how she missed them as much as she missed being independent. Delving deeper, we discussed how she was moved around the hospital in a wheelchair after suffering a fall at home using a walking cane. She hated the cane but would use it if there was a more stable and safe design.

This small insight into the daily struggle of what some people go through was enough to begin some concept development straight away, and as such, these conversations about mobility issues were a key fundamental notion considered when designing the product.

Finally, although the sample size is small to make any broad assumptions, the findings do reveal that students who engaged in the learning process experienced a noticeable sense of discomfort. 'Pedagogy of discomfort' indeed encourages students to step outside their comfort zones and embark on a critical examination of their own selves, including their deeply held beliefs, values, and assumptions. This discomfort aims to foster a sense of responsibility and accountability among students and promote the development of an empathetic outlook towards disadvantaged populations, who frequently encounter discomfort as a result of their marginalised status within society. [3].

6 CONCLUSIONS

Empathy is an important starting point in the design process. The students must understand the importance of empathic design early in their careers to ensure that one is not looking at the problem from a purely functional perspective. We also observed that novice designers struggle to empathise with users who are significantly different from them. Further, when engaged in empathy exercises in a classroom environment, they tend to confuse empathy with sympathy. We also found that the use of tools like empathy suites as part of the user-centric design process is not very effective as students take it as an academic challenge to overcome to complete course requirements rather than realising how it feels to be in that condition indefinitely.

To address the above problem, we have employed two strategies transformational teaching and the pedagogy of discomfort. In which we put students in a situation where they must negotiate uncomfortable situations as part of solving a real-life problem. The outcome of this strategy has shown us that this indeed disrupts students' preconceived notions design process. Pedagogical experiences of discomfort encourage students to question prejudice and to develop an empathetic attitude towards disadvantaged populations who are accustomed to experiences of 'discomfort' daily stemming from their marginalisation.

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MULTIDISCIPLINARY DAIRY MILK PACKAGING COLLABORATION

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ABSTRACT
There is a growing trend fostering interdisciplinary projects at universities, as scholars and students from different fields unite to tackle complex problems to real-world challenges. This research explores how 25 students from food science, industrial design and graphic design and three instructors from the same disciplines collaborated to address declining dairy milk consumption in the United States. The project had three phases (P): research, design, and innovation. In P1, student teams studied the dairy industry and packaging-related topics, including regulatory constraints, farm management, market and brand analysis, packaging technologies, and environmental impacts. In P2, individual students designed dairy labels for a 1-gallon US plastic jug and a ½ gallon US paperboard container. P2 designs were evaluated in a 100-person consumer sensory panel and a national survey reaching 619 people. In P3, student teams designed new environmentally responsible milk packaging forms and purchasing experiences. Results in P1 indicate that students working in multidisciplinary teams developed a comprehensive understanding of milk. P2 packaging results showed some difference between the sensory panel and the national survey, but a few designs performed well in both. P3 designs were not surveyed for this study. Educationally, students reported a mixed learning experience. Some embraced the challenges of a research-driven class project, while others found the disciplinary and cultural differences chaotic and emotionally challenging. The two-year difference between graphic and industrial students exposed professionalism differences. Instructors reported a positive educational experience but would train future classes on private vs public feedback, personal vs user-driven design narratives, and consumer-driven design ranking.

Keywords: Interdisciplinary design, multidisciplinary design, innovative milk packaging, multidisciplinary collaboration, multidisciplinary educational experience

1 INTRODUCTION
There is a growing trend fostering interdisciplinary projects at universities, as scholars and students from different fields unite to tackle complex problems and find creative solutions to real-world challenges in healthcare, law, and technology [1][2]. Design professionals and academics have demonstrated that multidisciplinary teams create increasingly robust solutions over individual disciplines [3][4]. Throughout the interdisciplinary process, students apply the methods of their domains, exercise critical thinking and rationality, operate technology used in the industry, and work in cohesion with cross-functional teams [5]. The greater the interaction students have with other disciplines, the more likely they will think critically from different perspectives, which can be channelled to create unconventional solutions to obstacles in their industry [5]. This design study presented students with an exigent challenge in the dairy industry — a 52% decline in fluid milk sales since 1970 in the United States [6]. Food science students introduced the design class to this issue because the former hypothesized that leveraging the packaging of dairy milk cartons and jugs could increase the product's attractiveness to consumers. The interdisciplinary nature of this study stemmed from the research and evaluation of packaging designs created in the class. Food science students shared their knowledge of consumer sensory science, the dairy industry, food regulations and laws, and statistics to understand the interaction between consumer attitudes and purchase intentions of proposed packaging. Designers shared their knowledge of narrative development, visual communication, and experience design.

Food science researchers analyzed the effects of packaging design on consumers through a consumer sensory panel and a national survey and presented statistical outcomes to the design class. Through all project phases, including the creation and feedback stages, it was discovered that several factors could facilitate or impede the interdisciplinary learning process to influence its potential value. These factors determine how enriching a multidisciplinary education is to students, including their level of motivation and interaction with the other disciplines before the class, personality, academic stress, and the learning environment [7]. This paper illustrates how disciplinary education and an interdisciplinary research project are undertaken in the classroom and represents the findings of the educational outcomes for the design and food science students and instructors.

2 METHOD

2.1 Participants

Participants included twenty-five students, twenty females and five males. Eighteen were second-year graphic designers, four were fourth-year industrial designers, and three were third-year food scientists. Designers were informed that their design work would be evaluated via a consumer sensory panel and a national survey and that designs and results would be presented to an actual client. All participants were undergraduate students at Brigham Young University. No students received extra credit or other forms of compensation.

2.2 Procedure

All twenty-five students and three instructors collaborated on the one-semester, three-phase (P) project: research, design, and innovation. The students periodically presented their work to the client, BUILD Dairy, a private enterprise that supports dairy research.

2.2.1 Phase One (P1): Research the Dairy Industry

Students were assigned to conduct research in teams of four to five, covering specific aspects of the milk production process. Groups thoroughly researched topics such as legal requirements for dairy milk labelling, Food and Drug Administration (FDA) and National Dairy Council nutrition facts, local dairy farm operation, dairy plant production, types of packaging, consumer trend analysis and experience mappings, and the environmental impact and sustainability of the industry. Miro, a visual collaboration platform, was implemented as a repository for data and to collaborate effectively, see Fig. 1. Students presented their experiential learning findings to the class.

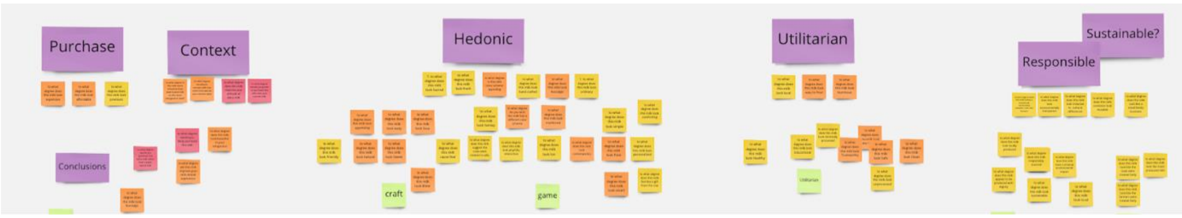

Figure 1. Miro Board Research

2.2.2 Phase Two (P2): Design Labels on Existing U.S.A. Standard Milk Packaging

Designers were given two weeks to create matching labels for the front and back of a 3.79-litre (1-gallon US) plastic jug and all four sides of a 1.89-litre (½ gallon US) paperboard container. Labels were based on newly designed narratives rooted in research from P1. All labels used the same company name, “Milkhaus”, corporate address, nutritional facts panel, and identical digital form assets, see Fig. 2.

Figure 2. Control Assets

For the sensory study, 100 panellists viewed 21 unique graphic designs. Panellists evaluated seven randomly-assigned images in each of the three sessions on separate days. Only the front panel images of each jug and carton pair were presented to simulate what a consumer would see first in a retail setting. Questions were presented, and data was collected by Compusense software. Image pairs were presented one at a time, with all questions being answered before continuing to the next one. Each jug and carton pair were presented side by side on the computer screen, with the jug always on the left, and were identified by a 3-digit code. Questions were categorized by theme and shown below the images. After completing the questions for all labels, all seven label pairs were presented on a single computer screen; panellists were asked to choose a label design from which they could taste the milk of their desired fat content (skim, 1%, 2%, whole), see Fig. 3. Samples were delivered to participants through a sliding window in a private booth, without interaction with the administrators of the panel. The university Institutional Review Board approved the sensory panel and the survey, and subjects were paid for participation. The panel and survey concluded a week after the final designs' completion.

Survey questions were divided into five categories with a total of 21 questions: purchase (4), hedonic (6), utilitarian (3), consumer behaviour (4), and responsibility (4). Participants rated the designs in sub-categories such as; level of environmental transparency, inclusivity of cultural differences, reusability, and the consensual relationship between cows and humans. Designs were presented to the client a week after completing the sensory panel and national survey. The success of a given packaging design was determined by comparing the significance of statistical means to the control.

Figure 3. Sensory Panel

2.2.3 Phase Three (P3): Designing a New Milk Experience

Students were divided into teams of four to five students to develop a new container and experience surrounding dairy milk. Each group collectively designed a unique packaging form and digitally generated 3D model in CAD. Students created their own dairy brand, reimagined the milk consumption experience, and designed the packaging based on the team's common new packaging form. Students relied on points of research from P1 and P2 to inform their designs, and Miro was again used as a tool for group ideation, see Fig. 4. A national survey was planned to measure the results of P3 but has not yet been administered.

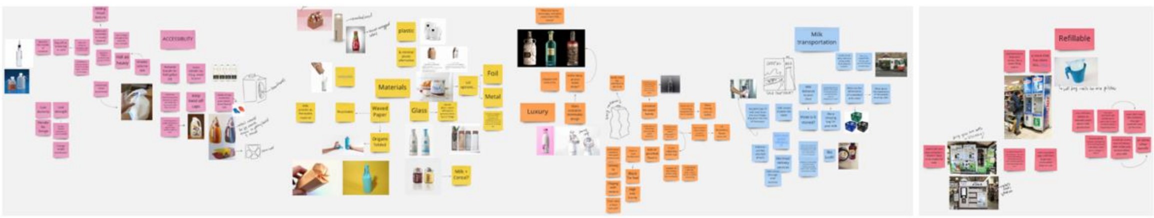

Figure 4. Group ideation for P3 direction

2.3 Data Analysis

The sensory panel results and national surveys from P2 were statistically analyzed using SAS. Student educational experiences were derived from personal interviews, class documents posted on Miro, and student course rating reports.

3 RESULTS

3.1 P1 Results

At the close of P1, student groups gave 20-minute presentations of their findings to the class, see Fig. 5. This allowed students to share gathered knowledge and gain an understanding of the domain. Industrial Design students offered information on packaging materials and manufacturing processes and mapped consumer experiences. Food Science students presented on dairy milk production, laws, and regulations. Graphic Design students discussed packaging trends and evaluated the environmental impacts of dairy milk production and consumption. Knowledge sharing was formative and vital to the study’s process, as it took the inputs of all disciplines to gain a full view of the milk industry ecosystem.

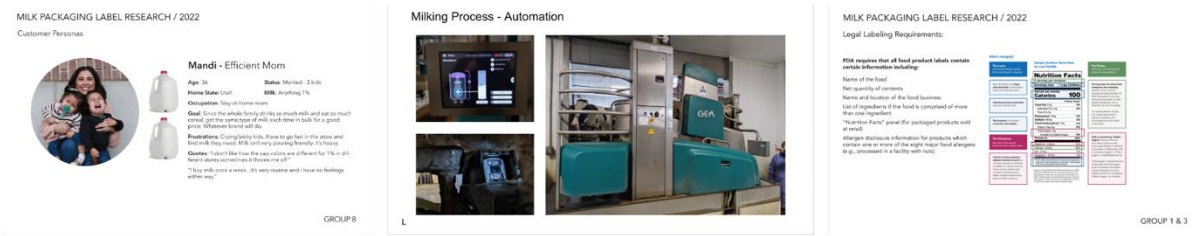

Figure 5. Excerpts from P1 research presentations

3.2 P2 Results

In P2, each student created a design for two standard package forms and a standard brand name. Images of these designs were submitted to the local sensory panel and the nationwide survey.

3.2.1 Sensory Panel Results

Results from this panel distinguished designs #914 and #189, as top performers overall and in the “likelihood to purchase” category, see Fig. 6. Despite these designs’ top scores, they were not leaders across all categories. Specific designs performed better than others in different categories, often dependent on the narrative which inspired the design. This finding suggests that graphic designs must reflect the initial brand goal or primary message of a company to be successful in communicating with consumers. This finding suggests that packaging designs must reflect strong messaging derived from brand values to establish effective communication with consumers.

Figure 6. P2 Top Performing Milk Packaging Designs in Sensory Panel

Following the collection and analysis of sensory panel results, findings were reported to the class. Statistics were explained to students, and results were presented using blinding numbers, allowing students to recognize only their ranking. Despite these efforts, graphic design students reacted negatively to this presentation. Student rating comments mentioned that reviewing the results “wasn’t helpful and felt discouraging.” Another student commented that the results created a “hierarchy” in the classroom.

3.2.2 National Survey Results

Top performers in the national survey were designs #914 and #459, see Fig. 7. Again, these ratings were the highest overall, but the survey results support the previous finding that targeted messages outrank overall performers in specific, relevant questions.

Figure 7. P2 Top Performing Milk Packaging Designs in National Survey

3.3 P3 Results

The four team concepts were: 1) a paper carton containing edible pods of milk made of seaweed-based plastic. 2) A rectangular reusable glass form, in conjunction with a milk-refill station in local supermarkets. 3) A compostable moulded paper pulp container lined with seaweed-based plastic. 4) A plastic carton with interlocking stacking abilities, allowing unique reuse in the home, see Fig. 8. These designs have not been publically assessed yet.

Figure 8. P2 New Milk Packaging Forms

3.4 Student Course Ratings

Student course ratings were mixed. The course scored 4.1 / 5 in student ratings, below university and department averages and a decrease in the course-specific historical rating of 4.6. Trends in student ratings mentioned feeling the emphasis on research (P1) took too much of the course's time. Incorporating research into the design process was new for many graphic design students. The sensory panel debrief negatively impacted student confidence and course social dynamics. Students excused the course as "experimental," commenting on unclear communication between instructors and students and disappointment over the efficacy of collaboration.

Despite these unflatering comments, several students praised the course's interdisciplinary nature and hoped for similar opportunities in the future. Many said it enhanced their learning by pushing them to think in a new way, such as a comment stating they "never thought about forms before" the course.

4 DISCUSSION

4.1 Connections

Students in graphic design, industrial design, and food science had the opportunity to cooperate on this research. Being in the same class enabled students to learn different disciplinary methodologies. The food science students brought a crucial understanding of the regulations and processes of the dairy industry. Despite students' working proximity in the class, some remained siloed in their discipline, while others formed lasting interdisciplinary friendships.

4.2 Collaborations

Collaboration was particularly strong at two points throughout the design process. In the P1 research phase, students worked together in multidisciplinary teams. Shared expertise at this stage made for a more comprehensive and informative research base. The second point of pronounced collaboration was in P3 where designers from mixed disciplines worked together to design a new milk packaging form.

4.3 Differences

Throughout the course, some graphic design and industrial design students felt tension when their approaches to design clashed. Graphic design students were accustomed to a personal aesthetic approach versus a user research-based approach by industrial design students. This difference in values and methodology was, at times, used to the team's advantage, pulling the best from each discipline. While other times a lack of respect for disciplinary differences led to a drought of energy and care for the project. The experience difference between second-year graphic and fourth-year industrial students was apparent. The older students demonstrated more professionalism and accountability about deadlines and disciplinary differences than the younger students, and when collaborating, the workloads between students were often lopsided.

4.4 Instructor Refinement

Instructors reflected on their experiences as an overall positive one. The food science instructor opined that this first attempt at multidisciplinary research was a fast and efficient way to introducing students to it. She stated that she would modify aspects of the class to address some adverse student outcomes. The graphic design instructor agreed that she found the study to be a valuable educational experience, but the cultures of the multidisciplinary students would have to be reconciled next time. Feedback communication styles proved to be a fundamental difference between the disciplines. The graphic design students were forced outside their comfort zone after the sensory panel results were discussed in class. The industrial design students were more accustomed to public project ranking and feedback. To better prepare students for the emotional toll of feedback, the graphic design instructor suggested that she would train students in ranking and deconstructing consumer feedback. Meanwhile, the industrial design instructor noted that the students' differences in knowledge, academic maturity, and professionalism were too extreme. Consequently, he would oversee this multidisciplinary research course again with students with similar academic maturity.

Concerning the client's interactions with the students, the instructors agreed that students would have benefitted if the client had a more significant presence in each project phase.

5 CONCLUSIONS

Despite the course's intent to provide a holistic education with a real-world challenge, the students, and instructors, experienced varying levels of success. Many students had little prior understanding of the dairy industry, and some were reluctant to work on a project they perceived as environmentally and humanely unethical. On the instructors' end, the different pedagogical cultures resulted in disruptions and impromptu changes during the semester, which caused stress to some students who preferred a set routine and fixed schedule.

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SUSTAINABLE PROTOTYPING CHALLENGES IN DIGITAL FABRICATION DESIGN EDUCATION

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ABSTRACT
Education in digital fabrication design involves an active learning environment where ideas are transformed into prototypes. The way design activities are carried out and the kinds of outputs are all impacted by this environment. Knowledge concerning sustainability practices and how it affects students' learning and skill acquisition is scarce. Therefore, the main goal of this study was to examine and evaluate learners' sustainability practices and educational experience in a digital fabrication class. A seven-week first-year university course covered the fundamentals of design and digital fabrication, including electronics design, embedded programming, 2D design, and 3D design. Students were encouraged to create and implement their own ideas by designing and building a physical prototype that interacts with its surroundings. They worked in teams and were required to document their process on a weekly basis. The documentation and the final design prototype were the main deliverables of the course. Sustainability requirements were integrated as evaluation criteria, including the use of sustainable materials, reusing components, building instead of buying, and easy-to-reuse project components. Data collected from student documentation, surveys, and prototypes were analysed to identify sustainable practices and learning aspects. Findings showed that sustainability as a process and sustainability about the final prototype should be addressed differently. This requires timely actions on sustainability by both students and instructors. Intervention programs should be aware of sustainability issues in digital fabrication without compromising design education, iterative prototyping, and learning.

Keywords: Digital fabrication, prototyping, makerspaces, FabLab, sustainability practices

1 INTRODUCTION
Digital fabrication design education is defined by an active learning environment in which prototypes are created from concepts. This is a defining feature of this field of education. This environment (i.e., digital fabrication laboratories or FabLabs) has an effect not only on the method in which design activities are carried out but also on the content that is learned and the types of outputs that are produced [1,2].

Fundamental digital fabrication classes have been incorporated into the university curriculum, especially in design education (e.g., [3]). The context of digital fabrication has the potential to affect how design is taught in higher education [1,2,4]. This environment determines how design activities are conducted (e.g., [5]) and how knowledge is obtained (e.g., [6]), as well as the types of outputs that are feasible (e.g., [7,8]).

However, there is currently a lack of knowledge regarding sustainability practices and how they impact student learning and skill acquisition. Therefore, the objective of this research was to assess learners' sustainability practices and educational experience in a digital fabrication course.

2 SUSTAINABILITY AND DIGITAL FABRICATION DESIGN EDUCATION
Digital fabrication affords the possibility of digital do-it-yourself (DIY). Previously, the substitution of mass production with DIY practices based on a more sustainable model has been contested. In some instances, digital do-it-yourself is less sustainable because the manufactured object may be considered replaceable [9]. The substitution of mass production with localized digital fabrication has various

implications for digital do-it-yourself, such as the novel combination of readily available resources and materials [10] and the customization of objects [9]. These repercussions demonstrate that personal digital fabrication practices may have varying impacts and outcomes. The repair and reuse of existing objects [10] as well as the use of local and recycled materials in the production of new objects [9,11] have been pursued for their high environmental value.

As a tool for design education, digital fabrication impacts both the process and the outcome. This scenario of digital fabrication education must cope with varied criteria for digital fabrication abilities, design skills, and sustainability [12]. However, the design education context typically does not permit a great deal of sustainability-focused experimentation [13].

At the universities, digital fabrication is regarded a curricular component aimed at the development of specialized skills [3]. To strengthen design education inside the digital fabrication framework, it is vital to appreciate sustainability challenges and recommend intervention strategies. Despite the fact that digital fabrication courses and design studios share significant similarities [1,3,14], the development and implementation of sustainable solutions remain a challenge. Digital manufacturing spaces, such as FabLabs, offer innovative technology in a well-organized environment that is accessible to a broad variety of stakeholders, independent of their level of experience [15]. FabLabs are open environments where students may meet persons from diverse backgrounds working in the same field and be exposed to fresh ideas and fields of expertise, hence raising the likelihood of unforeseen synergies and creativity [16, 17]. Furthermore, these environments open avenues for synergy between research and education [18].

Especially in digital fabrication classrooms, a systematic examination of sustainability is rarely the primary focus. Existing initiatives continue to focus on distributed production and its influence on environmental sustainability, mass customization and personalizing, and sustainability evaluation [13]. It has been observed that digital fabrication cultures differ in their emphasis on sustainability. This gap was observed between users interested in assessing environmental implications and those interested in tracking the rapid evolution of new digital fabrication technologies and materials [11]. The multiplicity of approaches within the FabLab context cannot be extended to certain distinctive characteristics [19], making it difficult to monitor and alter the consequences of sustainability and design education. Hence, sustainability must be emphasized in design education within the framework of digital manufacturing.

3 RESEARCH METHODOLOGY

To investigate the integration of sustainability in design education, we implemented a method that introduced sustainability requirements as an intervention in a digital fabrication course. We collected data through documentation from the course, its outcomes, sustainability grades, and a series of self-reported subjective evaluations.

3.1 Course and context

This study targeted first-year students participating in a 5-ECTS (1 ECTS equals 27 hours of effective work) digital fabrication course offered by a European institution. In terms of requirements, intensity, duration, and load, the course's qualities are typical of the curriculum. The instructional language was English.

The seven-week BSc course was intended to help build design knowledge and skills. Although it was part of the bachelor's degree program in computer science, it was open to all university students. As a result, it attracts students from diverse backgrounds and academic areas. This course is intended to prepare students to develop interactive physical prototypes with mechanical, electrical, and software components. Designing and fabricating mechanical and electronic components and integrating software in a microcontroller are the major activities. The course is organized into two sections: a series of six lectures followed by guided project work. During the first two weeks of the course, six lectures introduce the primary aspects of design and digital fabrication, including an overview of FabLab, the design of physical objects, electronics design, embedded programming, 3D modeling and printing, and 2D design. Students were encouraged to conceive and realize their own ideas by designing and constructing a physical device (gadget) that interacts with its environment throughout the course of the subsequent five weeks. The device must meet the following requirements: (1) it must be primarily composed of mechanical and electronic components designed and manufactured in FabLab; (2) it must have moving parts that can be controlled by software; and (3) it must include at least one sensor and one actuator, with the software responding to the sensor's readings.

We employ various data streams, including students' documentation, final prototypes, course grades, and self-reported measures in surveys to analyse sustainable practices and learning in the context of the course.

3.2 Sustainability requirements

In this study, the course under investigation utilized specific and comprehensive sustainability requirements as part of its evaluation criteria. These requirements included: (1) reusing components, (2) choosing adequate and sustainable materials, (3) building instead of buying, and (4) selection of easy to reuse project components of the project. Reusability refers to utilizing previously disassembled components from prior projects or considering the potential for reuse in the current prototype. Reusing electronic components and their connections is a common practice.

Students were introduced to the sustainability in digital fabrication framework, which identifies categories of design, material, process, and de-assembly related to a set of sustainability indicators [12], such as recycling, reusability, transportation, energy consumption, waste reduction, emissions, and end-of-life considerations.

Individual student performance was evaluated by the instructor, with the sustainability criterion graded on a scale of 1 to 5, where 1 is low and 5 is high, and accounting for 5% of the final course grade. High performance on the sustainability criterion was achieved when all sustainability requirements were met. The sustainability grade was assigned per team.

3.3 Data collection: Documentation and prototypes

To support their learning, students were required to document their process on a weekly basis, with the online documentation and final design prototype serving as the primary deliverables for the course. Table 1 provides an overview of the two main sources of data, including their type, time, and relation to sustainability information.

Table 1. Sources of data collection regarding sustainability of the digital fabrication course

Sources	Type	Time Frame	Sustainability information
Documentation	Introduction, Weekly records, Summary	Week 1, Weeks 2-7, Week 7	Alternatives considered, Iterations and their number
Prototypes	Final presentation and demo	Week 7	Implemented solutions

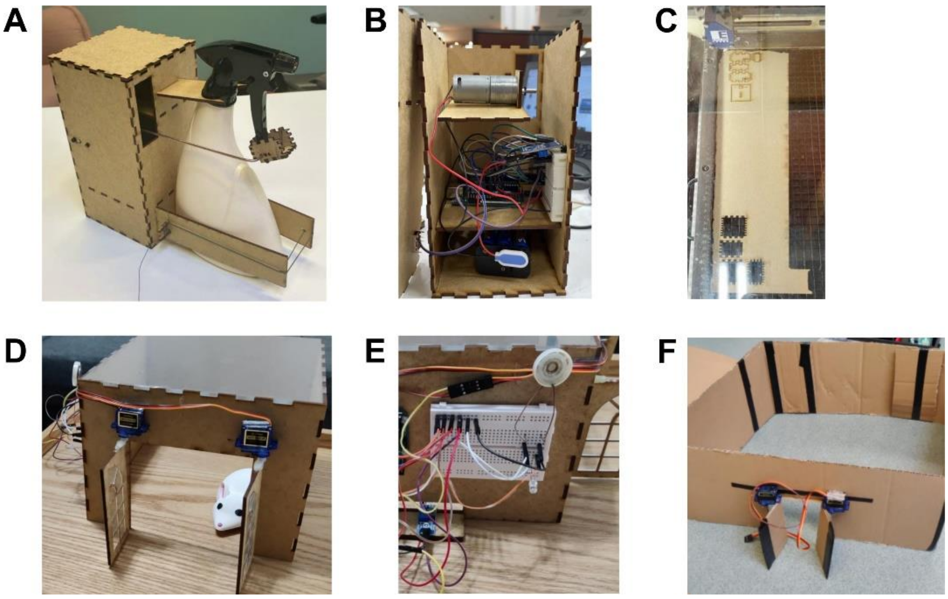

Figure 1. Examples of two prototypes and their sustainability characteristics: Refresher gadget prototype (A), its inner structure and electronics (B), laser cutting of some of the of its parts (C), and Mouse trap prototype (D), the electronics on its side (E), its early iteration made of cardboard (F)

Figure 1 showcases two prototypes and various aspects of their sustainability. The first prototype (Figure 1A) is a refresher gadget that detects high ambient temperatures and passing people to spray water. This mechanism is adaptable to different-sized bottles and considers de-assembly (Figure 1B). However, the production process is not optimized for minimal material use (Figure 1C), resulting in large spaces of unused material. The second prototype (Figure 1D) is a mouse trap that closes trap doors when detecting an object entering the space. This prototype also considered de-assembly (Figure 1E) and used materials with lower environmental impact for early iterations (Figure 1F)

3.4 Data collection: Survey

We gathered demographic information from the students and collected their post-course subjective evaluations of their experiences. The survey included four psychological dimensions, including perceived (i) skills, (ii) confidence, (iii) motivation, and (iv) enjoyment, which were represented by five technological dimensions: (a) 2D design, (b) 3D design, (c) electronics, (d) programming, and (e) use of tools and devices in digital fabrication. The survey utilized a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Out of the 96 students who completed the course, we collected 84 valid responses from the survey.

4 RESULTS

This section focuses on the relationship between the sustainability grades and the post-course subjective measures. Out of 84 students, 42 received a sustainability grade of 5, 27 received a grade of 4, and the remaining received a grade of 3.

We examined the correlations between the grades and the post-course subjective measures of skills, confidence, motivation, and enjoyment in each of the five technological dimensions of 2D design, 3D design, electronic prototyping, programming, and use of tools and devices. Out of all the skill measures in the five technological dimensions, only experience in 3D design and modeling showed a significant negative correlation to the sustainability grade ($r = -.296$; $p < .01$). There were no significant correlations regarding motivation measures in any of the five technological dimensions. Similarly, out of all the confidence measures in the five technological dimensions, only experience in 3D design and modeling showed a significant negative correlation to the sustainability grade ($r = -.266$; $p < .05$). Finally, out of all the enjoyment measures in the five technological dimensions, only experience in 3D design and modeling showed a significant negative correlation to the sustainability grade ($r = -.243$; $p < .05$). Overall, no relationships between the sustainability grade and post-course subjective evaluations of 2D design and modeling, electronic prototyping, programming, and use of tools and devices were observed.

5 DISCUSSIONS

5.1 Quantitative analysis of grades and post-course subjective measure survey

The negative correlations between sustainability grade and 3D design and modeling skills, confidence, and enjoyment in digital fabrication design education suggest that there may be trade-offs between the sustainability of a prototype and the level of expertise and enjoyment that students have in using 3D design and printing. These findings can be interpreted in two directions.

The first direction suggests that 3D design, and printing may not be the most sustainable alternative for digital fabrication prototyping in design education. Using alternative techniques such as 2D laser cutting or a combination of laser cutting and 3D printing might be more sustainable, which aligns with previous studies [12]. While 3D printing is an innovative and exciting technology that enables designers to create complex shapes, it requires a notable amount of energy and materials, and often produces waste. In contrast, laser cutting might be a more precise and efficient process that produces less waste and requires less energy. By using a combination of 2D laser cutting and 3D printing, students can achieve the best of both worlds - precise, efficient prototyping with minimal waste.

The second direction suggests that investing too much time and effort into 3D design might divert attention from actual hands-on resolution of sustainability issues. While 3D design and printing can be valuable tools for designers, they should not be the sole focus of a digital fabrication course. Sustainable design principles and practices should be integrated into the curriculum and emphasized throughout the design process. Students should be encouraged to consider the environmental impact of their designs and to explore alternative materials and processes that minimize waste and energy consumption. By prioritizing sustainability in the design process, students can develop the skills and knowledge needed to create innovative and sustainable solutions to real-world problems.

5.2 Qualitative analysis of sustainability

Results showed that the high-scoring design outcomes produced by the students included sustainability elements based on the use of materials and processes available in the digital fabrication laboratory. Students were concerned with the assembly and disassembly of reused components, as well as the reduction of generated waste and emissions, which was found to be critical for effective and sustainable digital fabrication practices. Sustainability, in terms of recycling and energy usage, relates to waste and emission reduction. Waste refers to excessive material use (see Figure 1C), and the initial ideation provides a crucial opportunity to reduce waste [20]. Design education interventions can optimize the prototyping process, mostly in the ideation phase (see Figure 1F), and eliminate wasteful iterations, mainly in the prototyping stage.

In general, the findings showed that sustainability as a process and sustainability about the final prototype should be addressed differently. This requires timely actions on sustainability by both students and instructors. Intervention programs should be aware of these sustainability issues affecting digital fabrication design, without compromising design education iterative prototyping and learning.

In addition to the reduction of environmental impact in prototyping and small series production provided by digital fabrication manufacturing, the final product designs have substantial environmental impact [11,13,20]. This perspective has implications for design education, and the findings of this study represent only a small part of the overall environmental implications.

5.3 Implications

Overall, educational interventions require timely actions on sustainability by both students and instructors. In terms of technology and methods, educational interventions should emphasize the understanding of a variety of possibilities and alternatives for materializing prototypes. Depending on the concept for the prototype, using a new digital fabrication process for the complete prototype construction could have a favourable effect on sustainability. Alternatively, decomposing the prototype's structure and materializing various components using various digital manufacturing techniques can also have a positive impact on sustainability. The focus of education should be on comprehending the characteristics, purpose, and sustainability consequences of numerous design iterations. Early design iterations, which are intended for learning, can be realized with low-fidelity materials that are leftover, salvaged, or repurposed (as shown in Figure 1F).

6 CONCLUSIONS

Our study of a digital fabrication design course revealed the importance of using specific materials and processes for different design iterations to achieve effective and sustainable digital fabrication practices. Intervention programs in higher education institutions aimed at digital fabrication courses in design may benefit from considering our findings. These will help to improve design education in suitability, particularly regarding aspects such as waste, emissions and reuse of components. Furthermore, our findings have implications for implementing sustainability in digital fabrication prototyping, particularly in small teams and startups engaged in product development. By incorporating sustainable practices in the design process, such as the use of sustainable materials and reducing waste, startups can reduce their environmental impact while also improving the overall quality of their products.

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DEMOCRATISING eHEALTH DESIGN: EMPOWERING HEALTHCARE PROVIDERS WITH HEALTHCARE DESIGN ABILITIES THROUGH A CO-CREATION TRAINING

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ABSTRACT
The market penetration of eHealth interventions is substantially lower than investors anticipated due to their low acceptance. Main causes include the use of top-down approaches and the tendency for research to concentrate on technology rather than service delivery from users' perspective. Healthcare professionals have exclusive expert knowledge of evidence-based practice in a specific area, which may explain why many eHealth intervention development projects continue to use top-down approaches. It is therefore crucial to empower healthcare professionals with design skills and mindset. On the other hand, the roles and responsibilities of designers in the twenty-first century have been controversial. Many farsighted designers assert that we are at a turning point of transforming design from an expert-driven process focused on objects and services within a taken-for-granted social and economic order towards design practices that advocates design-led societal transition toward more sustainable futures. To foster the transformation, design education should cater to all abilities. Health CASCADE is a Marie Sklodowska-Curie Innovative Training Network to consolidate co-creation as an effective tool to fight public health problems. Imparting the knowledge of co-creation in public health to healthcare professionals has the potential to alleviate the gap between design and healthcare, meanwhile provides opportunities for stakeholder participation in the development process to increase trust. This paper illustrates a curriculum development process partnered with a healthcare professional aiming for delivering knowledge of co-creation in public health to healthcare professionals working on designing eHealth programmes on the national healthcare support platform, 1177.se – Support and Treatment in Sweden.

Keywords: eHealth, co-creation, healthcare professional

1 INTRODUCTION
The burden on the healthcare system is growing as medical treatment advances, the aged population increases, and people's health awareness improves. eHealth is one of the prospective strategies to cope with this situation which has great potential to open up new avenues to the health system. Most recently, the COVID-19 pandemic has intensified the focus of the development of eHealth interventions [1], potentially due to quarantine policies and the large amount of health resources allocated to COVID prevention and treatment [2]. Despite tremendous progress, the development of eHealth interventions is fraught with difficulties. There is a paradox in that there are a variety of eHealth interventions accessible on the market, but their market penetration is now substantially lower than investors anticipated due to their low acceptance. It may result in a waste of effort and resources. The sustainable development of eHealth interventions can be categorised as one of the wicked problems in the twenty-first century as it is morally repugnant for the planner to address and has spread across the board [3]. Due to limited evidence on optimum leverage points, the waste is likely to endure. The reasons for the lagging development were identified in the following aspects. A) The use of top-down approaches and the tendency for research to concentrate on technology rather than service delivery from users' perspective are part of the main challenges for current eHealth intervention development projects [4]; B) eHealth is being mass-produced and its legality are being debated [5], which may undermine its original goal of

improving healthcare delivery by eroding user trust; C) as eHealth intervention development is available to developers without professional medical training, various studies have highlighted concerns regarding the quality of eHealth interventions and the medical information they contain [6]. One of the consequences of unsubstantiated medical information circulation is ‘infodemic”, defined as “too much information including false or misleading information in digital and physical environments during a disease outbreak which causes confusion and risk-taking behaviours that can harm health” [7].

It is commonly stated that research evidence takes an average of 17 years to reach clinical practice [8]. If the translation process accelerates in the right way, the return on investment in research will rise. Healthcare professionals may be able to advance the process of "research into practice," which is converting promising interventions in clinical research into healthcare practice [8]. Healthcare professionals are trained to provide evidence-based care for patients and have expert knowledge of evidence-based practice in a specific area. Their knowledge is, to some extent, exclusive, which may be one of the reasons why many eHealth intervention development projects continue to use top-down approaches. They may have preponderance to have the initiatives on eHealth development to deliver evidence-based care due to their specialised knowledge, networks in the relevant field, and hands-on clinical experience. Nowadays, with an increasing emphasis on patient-centred care, which focuses care delivery on patient needs and preferences, it is necessary to maximise and optimise the engagement of patients and other stakeholders in the intervention development, as well as incorporating implementation considerations in the early stages [9]. Although some of the eHealth intervention development reports produced by healthcare professionals incorporated concepts such as human-centred design, user-centred design, participatory design, and so on [10-12], the lack of design knowledge and experience limited their capacity to use interactive methods. Most of the studies involving patient and/or other stakeholders in the eHealth development process rely excessively on traditional interviews and focus groups. These methods are well suited to pose direct questions, but therefore have a limited ability to elicit tacit knowledge [13]. Additionally, the multidisciplinary nature of eHealth and the rapid pace of technology development cause challenges in eHealth development projects initiated by healthcare professionals. It is difficult to combine different approaches from the fields of healthcare and technology. Research and dissemination in global public health moves at a slower pace than technology development, beginning with formative research, followed by measuring efficacy, and then effectiveness [8]. It is critical for healthcare professionals to have access to and comprehensive knowledge of how to partner with end users and other stakeholders in the eHealth development process to facilitate initiatives proposed by them and avoid top-down approaches in eHealth development projects. Design education has been applied to medical education, and it has been argued to be important for addressing the challenges posed by complex health care problems [14]. It is therefore crucial to empower healthcare professionals, who are working with eHealth intervention development projects, with design skills and mindset. On the other hand, the roles and responsibilities of designers in the twenty-first century have been controversial. Many farsighted designers assert that we are at a turning point of transforming design from an expert-driven process focused on objects and services within a taken-for-granted social and economic order towards design practices that advocates design-led societal transition toward more sustainable futures [15]. To foster the transformation, design education should cater to all abilities. However, it is challenging to initiate and design the tailored courses for healthcare professionals, as they have diverse professions and are uninitiated in design skills.

Health CASCADE is one of the European Union-funded multidisciplinary expert networks with the ultimate goal of delivering the rigorous scientific methodology to consolidate co-creation as an effective tool to fight public health problems [16]. Imparting the knowledge of co-creation in public health to healthcare professionals has the potential to empower them with design skills and mindset in an appropriate way. Knowledge of co-creation may help to alleviate the gap between design and healthcare, meanwhile providing an added value of opportunities for stakeholder participation in the development process to increase trust. This paper illustrates a curriculum development process partnered with a healthcare professional working with 1177.se – Support and Treatment (1177.se - Stöd och Behandling) in Sweden. The aim of the curriculum is to deliver knowledge of co-creation in public health to healthcare professionals who are responsible for designing and publishing eHealth programmes on the national primary health care support platform, 1177.se – Support and Treatment in Sweden. 1177.se – Support and Treatment platform is well-known and credible by Swedish population. However, scientific studies using proper study design on tools available at this platform are rare. The reflection on the curriculum development process contributes to the notion of empowering healthcare professionals with healthcare design abilities.

2 CO-CREATION IN PUBLIC HEALTH

Co-creation has become increasingly popular in a variety of scientific disciplines in recent years. In research projects involving the development of public health interventions, funding and governing bodies are increasingly encouraging end users and other stakeholders to participate in the development process to bring about beneficial societal changes [17]. However, there is a no standardised definition of co-creation in developing health interventions. Other terms that are frequently used in the literature include co-production and co-design [18,19]. Co-creation differs from co-design and co-production because of their different emphasis placed in practice based on their different characteristics and origins [18,19]. Co-creation is focused on an iterative process, involving various stakeholders throughout the process, as well as creative problem solving. Co-design can be considered as a specific instance of co-creation and may also be considered as a collective design process between designers and those who are not trained in design, while co-production may place more emphasis on implementing determined solutions using existing resources [18,19]. But the terms are often reported interchangeably. There have been recent calls for moving towards authentic and meaningful ‘co’ approaches [17]. Some of the research reported that co-creation practice appeared to limit the patient's role to functioning as an information provider rather than an active co-creator [20]. Health CASCADE aims to fill an important gap in knowledge, as surprisingly there is a lack of research investigating the validity of these claims and quantifying the actual impact of co-creation in public health. One of the primary tasks of Health CASCADE is to cascade co-creation skills and expertise by training a new community of professionals capable of working across disciplines, and public and private sectors. There is a need to disseminate this knowledge to the many actors that will, ultimately, engage with local stakeholders to co-create new interventions within their localities and regions. As an attempt, Health CASCADE launched the Evidence-based co-creation Masterclass and Guidelines. The researchers in the field of public health responded favourably. This project aims to further disseminate the co-creation knowledge to healthcare professionals working with eHealth programme design.

3 METHODS

Three co-creation meetings with a healthcare professional working with designing and publishing interventions on 1177.se – Support and Treatment in Sweden were held on 21st Oct 2022, 26th Oct 2022, and 8th Nov 2022. Following each meeting, the healthcare professional discussed with team members who work as digitalising business developers and brought the team members' opinions to the next meeting. 1177.se – Support and Treatment in Sweden is a well-known and established national healthcare support platform for publishing online evidence-based health interventions. According to studies, the development of eHealth interventions should consider contextual factors, fit into daily routines, and not jeopardise the existing hierarchy between patients and healthcare professionals [21-23]. Every residence in Sweden has access to 1177.se – Support and Treatment, which has an advantage when publishing eHealth interventions as it is a part of the current national care process.

Table 1. Curriculum development process

Meeting	Description	Format
No.1 (21st Oct)	1. The healthcare professional gave examples of the previous and ongoing team projects on 1177.se – Support and Treatment, as well as an overview of the process for each eHealth intervention from initiative to launch; 2. Discussion on the benefits and drawbacks of the Inera-enabled eHealth programme builder, which is used to design and develop eHealth programmes for the 1177.se – Support and Treatment	Digital (2 hours)
No.2 (26th Oct)	1. Discussion of potential challenges and solutions for putting the co-creation sessions into action; 2. Discussion on the benefits of implementing co-creation sessions; 3. Co-created the initial curriculum draft.	Offline (2 hours)

No.3 (8th Nov)	1. Evaluation on the developed curriculum.	Offline (2 hours)

(More meetings are scheduled.)

4 RESULTS

4.1 Inera-enabled eHealth programme builder for the 1177.se – Support and Treatment

Inera is a company owned by regions and municipalities in Sweden. The mission of Inera is to create conditions for digitalising welfare, by providing the owners with common digital infrastructure and architecture. 1177.se – Support and Treatment is one of the e-services Inera is responsible for. Most of the eHealth programmes that are designed via Inera focus on fostering improved patient-healthcare provider communication and/or disseminating evidence-based knowledge for disease management. One such co-created eHealth intervention is Min KOL (i.e., an interactive application to promote the self-management skills among people with COPD, and meanwhile improve the communication between patients and healthcare providers), which was published on 1177 via the Inera platform [24]. The creation of Min KOL demonstrated that the incorporation of co-creation practice in the development process had a significant positive impact on the final product.

Six advantages of Inera were identified through the meeting with healthcare professionals: a) Consistency, b) Authority, c) Usability, d) Inclusivity, e) Connectedness, and f) Data management.

a) Consistency. The platform follows the same protocol for every intervention published, which makes the interventions accessible for users by not requiring additional system learning.

b) Authority. As 1177.se is a national medical information system under the Swedish Medicines Agency, the authority contributes to the user trust. Data security is ensured.

c) Usability. Inera provides a design-friendly environment for healthcare professionals to develop interventions without professional human-computer interaction skills.

d) Inclusivity: All healthcare professionals who are in charge of creating eHealth interventions on the platform underwent the required training. Every intervention must be accommodating to people with achromatopsia, as well as those with hearing issues and vision problems.

e) Connectedness. The eHealth intervention designed by one region can be asked to share the transparent design process. If it is too complicated to learn, it can be adapted by another region through a region payment.

f) Data management. Patients use their identity number to login to the platform, which allows data to be traced and contributes to continuous care support. Healthcare professionals use their id-card (i.e., known as the Siths-card) to access the system. It ensures the security of the e-service.

The challenges of using Inera identified by healthcare professionals are around publicity, interactivity, and compatibility. When a well-developed eHealth intervention is not widely used, issues in the publicity arise. Before the launch, an implementation plan should be developed in collaboration with stakeholders. When it comes to creating eHealth interventions, the Inera platform is constrained by its modular functionality. Healthcare professionals suggested gamification to increase the user acceptance towards the interventions, but they also described it as challenging to implement on the Inera platform. Another challenge is that the platform is separated from the electronic medical record system. Healthcare providers has many separate systems to login to so it´s a challenge to introduce another system to them.

4.2 The perspectives of the healthcare professional team on implementing co-creation sessions

Healthcare professionals endorsed the notion of implementing co-creation sessions. They claimed that the co-created eHealth interventions may be more easily accepted and spread because stakeholder input can be incorporated throughout the development process. After receiving specialised co-creation skill training, healthcare professionals believe they can feel more confident about advancing their co-creation skills. However, the specific issues brought up by healthcare professionals centre on how to design a tailored co-creation process for the intervention target population. Healthcare professionals brought up the issue of not having guidelines to adhere to when creating eHealth interventions. They acknowledged the potential value of co-creation but noted the lack of readily available resources.

4.3 Curriculum

Table 2 shows the three phases of the curriculum: groundwork, development, and design. It will be tested, and feedback on potential improvements will be collected.

Table 2. Curriculum for co-creation sessions

Phases	Session objective(s)
Phase 1	1. Learn about the definition of co-creation in public health; 2. To comprehend why co-creation is needed in health care; 3. Demonstration on case studies of co-creation employment in the eHealth intervention development;
Phase 2	1. To learn how to facilitate co-creation sessions with stakeholders and how to get input from patients and other stakeholders;
Phase 3	2. To improve human-computer interaction design skills; 3. To be aware of principles of gamification design for eHealth;

5 DISCUSSIONS

From the curriculum development process with healthcare professionals, we discovered that co-creation sessions are desired and valued by them. They concurred that the incorporation of co-creation practice in the development process may improve user's adherence to eHealth programmes. A practical guidance and checklist tailored for healthcare professionals will be helpful in addition to the course. The curriculum development procedure and the course design have the potential to be adapted into a new context, even though we specifically chose a particular context to partner with for course design. Adapting the course that worked elsewhere can save resources associated with developing new courses for each specific context. Additionally, co-creation knowledge has great potential to close the gap between design and healthcare. The learning process can be expanded to include more design techniques and methods, which aids in disseminating design education among healthcare professionals.

6 CONCLUSIONS

Co-creation offers a rigorous method for involving end users and other stakeholders actively in the development process, which has great potential for providing design education for healthcare professionals. This paper offers reflections on the curriculum development process that will aid in future co-creation training development for healthcare professionals.

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SUSTAINABLE INNOVATION THROUGH DATADRIVEN DESIGN USING LIFECYCLE ANALYSIS (LCA) METHODOLOGY

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ABSTRACT

The project sought to bring together fifty-four students enrolled on Nottingham Trent University's (NTU) BSc Product Design course and seventeen international exchange students (enrolled onto the European Project Semester - EPS) to work with industry partners, Alpkit and Design Matter with the common goal to reduce the embodied carbon of an existing Alpkit product; the Soloist tent. Both industry partners shared a common value of innovation through sustainability using Life Cycle Analysis (LCA) Methodology. Alpkit, a B Corp business had already established measures to track their social and environmental impact. Working with us, they sought to both improve their product credentials but also to support the education of young people to consider the impact of their decisions and design choices and the consequence on the sustainable values their product could achieve. The challenge that we set the students was to further push the boundary of one of their biggest selling products: the Soloist tent and explore design solutions that would further reduce its already streamlined carbon footprint, through the use of Life Cycle Analysis (LCA) methodology. The goal was to embed this in their learning to further add value to their design thinking in future projects. This presented an opportunity for students to learn how the use of product development and innovation can be gained not just through large shifts but also through many small gains, seeking granularity in design changes.

Keywords: Responsible innovation, collaborative/cooperative learning, design sprint, product design education, sustainable development

1 INTRODUCTION

A full product lifecycle analysis (LCA) is an in-depth exercise that looks at all of the sustainability factors that are attributable to a given product including, but not limited to water use, ore use, land use in addition to calculating pollutants such as carbon dioxide. An LCA would normally be undertaken by a specialist sustainability consultancy (SC) over a long period of time, with substantial collaboration with the product manufacturer and typically at a significant cost. For the European Regional Development Fund (ERDF) Sustainability in Enterprise project (SiE), and the Alpkit Design Sprint, the metric which was focused upon was carbon reduction. The Product Design aspect of the SiE programme offered Alpkit the opportunity to have the carbon footprint of one of their existing products assessed, followed by the product being redesigned or modified with the aim of reducing its carbon intensity. The carbon footprint of the proposed re-design would then be calculated to predict potential carbon savings. The aim of the project was to introduce students to the LCA process and embed the use of a toolset that would help them to consider the granularity of design changes and the impact that their decisions would make to reach the objective for the project; to improve the sustainable credentials of the Soloist shelter manufactured by Alpkit. The scope of the project meant that students would develop their skills through the utilization of tools used to perform LCA and critically investigate their own design solutions and specifications to improve the carbon footprint and further deliver benefits to the user with improved design considerations. Incorporating design sprints within education is well documented [1-3], providing a focused activity where new active learning tools can be successfully introduced. In addition, researchers have noted that innovative outcomes are enhanced through design sprint activities [4]. Having previously delivered a number of design sprints with larger groups [5], we included an immersive two-day lead in to introduce students to a new sector and new tool to support the LCA process. In recent years, sustainability education and the topic of LCA have become increasingly important in higher education institutions (HEIs). Despite the adaption of LCA education in curricula, there is still a gap in concrete examples of LCA teaching in the academic literature [6]. This case study aims to help fill this gap in the literature by sharing our teaching experiences on the subject of LCA.

2 DEVELOPING AN INTEGRATED LCA PROCESS

The process of conducting an LCA involved students identifying each material component, weighing and inputting data into an excel spreadsheet with preloaded values matching that of the materials. UK ICE material conversion factors for 2021 were used within the spreadsheet to provide carbon equivalent emissions. The conversion factors accounted for cradle to grave process including extraction, primary processing, manufacturing and transporting of materials to the point of sale. The emissions of each material were then added up and proportioned according to their relative weights, resulting in a value that took into account the product, packaging, use, repair and end of life. The main objective set for the project was to use carbon reduction as the key metric. Students also considered circular economy principles and the 5 R's: Refuse, Reduce, Reuse, Repurpose and Recycle.

2.1 Development of bespoke tool

A sustainability consultant (SC) was assigned to the programme to develop the tool and to oversee the results of each product evaluation/redesign. To assess the carbon footprint of a product, SC would typically employ specialist software and use their access to dedicated databases to gather data. They would then use their expert knowledge to assimilate the data to calculate a carbon intensity figure. Such software requires in-depth training and specialist knowledge to use. SC therefore developed a simple screening LCA tool for the SiE and the design sprint based around an MS Excel spreadsheet. SC recommended that weight be used as a unit of measure and populated the spreadsheet with pre calculated carbon intensity figures by weight (carbon per gram) for a wide range of commonly used materials. Furthermore, carbon data for transport per mile (based on mode of transport) was included in addition to end-of-life carbon intensity data and specific carbon data for a range of manufacturing processes (e.g., injection moulding). This data was stored on a dedicated carbon worksheet. A simple user interface sheet was then designed.

The interface sheet required the designer/student to break the product down in to its component parts and populate the sheet line by line. The interface sheet used drop down menus for many of the cells, using material from the prepopulated carbon worksheet, allowing the student to easily and accurately populate the sheet. Once a line for a given component was completed, the spreadsheet would use the weight to calculate a carbon figure for each line/component. The interface sheet also contained formulas that would add all carbon figures together, giving a final carbon emissions figure by weight for the product, this figure would be clearly presented on the worksheet. In addition, a graphical worksheet was created that automatically created bar charts and pie charts to give a graphical representation of how the different components and materials used to make up the product proportionally contributed to its overall carbon intensity. A specific part of the interface sheet was dedicated to the product's packaging and used exactly the same methods to obtain data and calculate the carbon figure. Finally, a data collection sheet was drafted, which laid out a standardised format for the bill of materials data that was required to undertake the screening LCA exercise. In the event that a material was entered on to the data collection sheet that wasn't already included on the Screening LCA tool, SC would obtain the carbon data needed and add it retrospectively to the tool. Apart from the minor expected teething issues when the tool was first used, the basic design of the Screening LCA tool was successful, remaining the same throughout the SiE programme. It became apparent initially that more complex materials would need to be included and SC was required to add new materials to the carbon worksheet quite frequently, this requirement diminished as the programme matured.

2.2 Professional engagement

The project involved key contribution and engagement from industry partners Alpkit and Design Matter. Alpkit provided the challenge area and supported setting the brief with us. Design Matter provided training on the use of LCA and access to the tool which students used throughout the project. Working alongside us Design Matter tailored their existing tool to create a beta version embedded with data to support the project area, with values to reflect the materiality of the existing product and further additional materials that students may consider. Together we defined a baseline carbon figure for the Soloist tent which the students could use to compare their own product against.

2.3 Preparing and planning for the Project

In addition to the two-week project, we engaged the students in a half day tear down activity to introduce them to the level of detail required for the project and selected an additional Alpkit product to conduct a tear down on; the Qark head torch. We introduced the students to the granularity of design through accurately recording each component weight. Simple scales, with a resolution 0.01 grams enabled the students to complete a detailed Bill of Materials (BOM). Alpkit's disclosure of their level of granularity for their tear down analysis helped us to mirror this in our own process to achieve parity of information. Students worked in groups of six for the lead in activity to support their learning with the Qark torch tear down. The pre activity allowed us to trial how students worked in larger group but also test how fast they picked up the detailed level required of the project to give them confidence going forward.
Group size continued to remain large for the tear down of the Soloist tent due to the availability of product. However, for the design sprint, the project groups were scaled down; from group size of fifteen to group size of three to five students. The larger groups supported their collaborative learning at the early stage of the project whereby students self-supported each other sharing information and learning the toolset. Whilst the design sprint operated with smaller group sizes of three to five persons. Due to the nature of the design sprint process smaller group sizes supported focused activities whereby group members could progress quickly through the process with an intensity to drive outcomes.

3 METHOD

3.1 Project outline

The project was delivered over a two-week period. The first week involved a two-day immersion into both the brand and toolset. Whilst the second week involved a five-day design sprint process.
Week one, for our first day; students were split into two groups and rotated between Alpkit's head office and retail store located in Hathersage, Peak District, Derbyshire. The experience at the head office included a briefing describing the brand values of the company and comprehensive tour of the whole site including packaging, warehousing, assembly and machine shop where they were given an opportunity to make their own sewn product. The visit to Alpkit's retail store enabled the students to gain an insight into the brand expression and marketing of the full range of Alpkit's product. Students also visited a competitor retailer which provided insights into other outdoor brands and products.
Day two involved immersion into the LCA tool. Students were reintroduced to the LCA process and tool set and then asked to tear down the Soloist tent and input the data into the tool. Having completed the tear down of the Qark headtorch a month earlier the students had familiarity of the level of granularity and accuracy that was needed for the LCA.
For the tear down of the tent, students were divided into groups of fifteen, to spread the level of work, but further to collaborate and learn from each other. We found that the teams divided themselves in a number of ways based on interest of the activity and the level of involvement of individuals, sharing knowledge of ways of disassembly of components of the design i.e., stripping down seams, unpicking labelling. The tasks developed their teamworking, leadership and further organizational skills, managing many people across different tasks and handling allot of detailed data. Having previously defined the baseline carbon footprint for the project we used this to check the students concluding 'as is' LCA for the Soloist and provided guidance to adjust where we saw discrepancies, so that all groups were all aligned with the same baseline values. This baselining activity was critical for students to learn about the product, test the tool and work as a collaborative group. Having the two days upskilling not only allowed for focus to then design, but also enabled time for students to gain new skills on using the tool and also knowledge of a new sector.

The week-long sprint process followed, where students were grouped in smaller teams of groups of three. We shaped the first day to enable Alpkit to share insights to the rational on all elements of the detailed design of the Soloist tent and further manufacturing and specialist knowledge on materials across other product ranges to inform and upskill students. Day two; focused on further research and exploration of ideas, utilizing the tool to test materials to see the impact that they would have on the carbon figures. Exploration was also sought in regard to packaging and removal of components. Day three; involved further design exploration leading to development of a single focused idea. Day four; involved prototyping, compiling the evidence including their LCA data to fully justify their design proposals and fully communicate their idea. Day five; students pitched their ideas to the client.

During the sprint week, a Soloist tent was erected as a reference point for the students to further interrogate and check back against. Many students used this to check materials, construction, testing size and familiarity with the physical product to compare back with the changes they were making. As students moved through the design process the LCA tool was used to explore materiality and weights, used iteratively as ideas were developed/ explored. As students suggested new materials the toolset further was evolved, and new data imported into the excel spreadsheet so that it was up to date with the latest thinking and considerations of the students. The tool was kept live and evolved a number of times to ensure data was current to support students' enquiries. We declared a 24 turnaround for update to the spreadsheet, but this often was quicker due to the reduced timeframe of the project and the need to keep the toolset relevant at all times. The conclusion of the sprint resulted in students pitching their ideas in a five-minute presentation to Alpkit supporting their process and final proposal with data in which every student declared a carbon reduction.

3.2 Assessment of students' experiences

The sample of the study consisted of fifty-four students enrolled in NTU's BSc Product Design course and seventeen international exchange students enrolled in the European Project Semester (EPS) programme. The students were asked to make anonymous self-assessments of their sustainability knowledge and professional skills before and after the project. Data were collected online through pre- and post-surveys administered to the students between October 25 and November 15, 2022. The same questions were used in the pre- and post-surveys. The pre-survey link was shared in the online study room on the first day of the course, and all students in the class were asked to complete this questionnaire after the project was introduced. The number of students who responded to the pre-survey was 33. The post-survey was performed after the project with the same method and 31 responses were received. The questions in the surveys were asked using a 5-point Likert scale. The low engagement of the survey was a result of launching the survey face to face when the whole student cohort would not have been present. Despite keeping the survey open and promoted, it was hard to re-engage after the initial introduction, as all students were rarely present at the same time.

4 RESULTS

The overall success of the project has been of interest to many parties. The work has been leveraged into the development of a number of case studies to promote the methodology and promotion of engaged partners including the SiE team and Nottingham Trent University Courses. Moreover, the project has led to student ideas being selected by Alpkit to develop and progress to manufacture which has commercial benefits for both students and also industry partners. In addition, this project has been selected as a case study for the University to promote Work like Experiences (WLE) for students across all sectors to promote the growing embodied academic integration of sustainability tools and methodologies.

4.1 Student proposals

Each of the student's final proposals incorporated a number of carbon saving ideas. Proposals included the use of alternative materials such as banana fibres or Titanium Dioxide, replacement of polyesters and nylons, or magnesium Ze-62 in lieu of aluminium. Furthermore, design interventions included optimizing the performance and functionality of the product–to either integrate new systems and remove materials, improve on the weight of existing product or redesign of existing details.

Student group ten took a more original approach. By maintaining all the original materials, they redesigned the Soloist to reduce material consumption and product weight. They also further increased the overall useable space of the Soloist. Alpkit's feedback reflected the success of Group 10s proposal:

'These are principles we try to apply to any redesign in the outdoor industry: to decrease waste; decrease weight; and improve performance. We were so impressed by Group 10's redesign of the Soloist that we are now developing their ideas into products.' [Industry Partner 1]

Apart from the selection of Group 10's idea to further be developed as a prototype to manufacture and launch. The output of the whole group led to ideas that Alpkit have considered for their Soloist product and collectively presented an opportunity to achieve a total carbon reduction for the Soloist of 5.55kg (c.31%), resulting in a total potential reduction in their annual carbon emissions by 16849.8kg from just one product. The design changes that students proposed which would contribute to this included the use of recycled materials, eliminating waste in production, redesign of the pole hubs to reduce weight & consumption, tweak to dimensions and structure, improvement to packaging, prolonging useable life with improved care instructions & repair kits.

4.2 Student and industry feedback

Students have recognized the value of using date driven design to seek improvements in their projects and design in a more sustainable way. Student feedback highlighted:

'This experience ensures that I will have a greater understanding of the challenges and process of calculating what impact a product will have on the environment.' [Student A]

'I gained the understanding of how to properly use an LCA tool allowing me to reduce the carbon footprint of my own future projects to produce a more realistic piece of work.' [Student B]

Whilst industry partners commented:

'The Life Cycle Assessment of our Soloist tent has been a hugely beneficial process for us. Every project presented to us by the NTU students has provided us with invaluable knowledge that we can action immediately or plan for the long term.' [Industry Partner 1]

4.3 Comparison of pre/post-project results of student's self-assessment scores

Table 1 presents the students' mean scores for their self-assessments of sustainability knowledge before and after the project. The students had higher level of knowledge on life cycle assessment after the project (M=3.80, SD=0.13) than before the project (M=2.96, SD=0.15). Likewise, they had higher level of knowledge on sustainable materials after the project (M=3.74, SD=0.13) than before the project (M=3.39, SD=0.15). In addition, the students' responsible production and consumption scores were compared before and after the project, and their knowledge level after the project (M=3.35, SD=0.11) were found to be higher than that before the project (M=3.21, SD=0.16).

Table 1. Students' self-assessment scores for sustainability knowledge before and after the project

Sustainability knowledge	Before the project (N=33)		After the project (N=31)	
	Mean	SD	Mean	SD
Life cycle assessment	2.96	0.15	3.80	0.13
Sustainable materials	3.39	0.15	3.74	0.13
Responsible production and consumption	3.21	0.16	3.35	0.11

N - total number of participants; SD - Standard Deviation; Scale - 1- Not at all knowledgeable, 2- Slightly knowledgeable, 3- Moderately knowledgeable, 4- Knowledgeable, 5- Very knowledgeable

Table 2 presents the students' self-assessment mean scores for professional skills before and after the project. The students had mean scores for higher teamwork skills after the project (M=4.29, SD=0.11) than before the project (M=4.24, 0.11). Likewise, there was an improvement in their presentation skills after the project (M=3.83, SD=0.15) compared to the pre-project period (M=3.45, SD=0.17). There was also an improvement in the students' critical thinking skills after the project (M=4.03, SD=0.11) compared to the pre-project period (M=3.90, SD=0.10). However, no improvement was observed in their communication and innovation/creativity skills after the project compared to the pre-project period. This may be because the students already had high self-assessment scores for communication and innovation skills before the project, leaving little room for further improvement.

Table 2. Students' self-assessment scores for professional skills before and after the project

Skills	Before the project (N=33)	After the project (N=31)

	Mean	SD	Mean	SD
Teamwork	4.24	0.11	4.29	0.11
Presentation	3.45	0.17	3.83	0.15
Communication	4.09	0.15	4.06	0.13
Innovation/Creativity	4.00	0.11	3.93	0.11
Critical thinking	3.90	0.10	4.03	0.11

N - total number of participants; SD - Standard Deviation; Scale - 1- Very poor, 2- Poor, 3- Average, 4- Good, 5- Excellent

5 CONCLUSIONS AND RECOMMENDATIONS

Using LCA data, students found opportunities to further enhance and improve existing product resulting in proposals that have been prototyped for manufacture. The collaborative structure of the project which included large groups at the start of the project and smaller localised groups for the main sprint supported the students learning of a new tool and further developed their critical thinking as evidenced from the results drawn down from the survey.

Recommendations resulting from the delivery of this methodology include:

#1 Plan a pre-event tear down of a similar product to embed the granular level of investigation into the project and familiarise the students with the product sector.

#2 Schedule in a lead in day to develop awareness of the brand. Where possible this should involve a visit to the office / manufacturing site to understand the culture and operations of the business whilst also a visit to the retail environment (if applicable) this will provide a full end to end immersion and depth of the brand values that the students are required to understand in redeveloping an existing product.

#3 Schedule a day to embed the theory of Life Cycle Analysis (LCA) and further test its application through the use of the tool set in an exercise to undertake the baseline LCA for the existing product.

#4 Ensure the LCA toolset embeds alternate materials so that students are supported throughout the design process and iteration cycle of their design concepts. Such that the cycle of iteration flows freely with the use of the tool driving design decisions.

The conclusions drawn from evaluation and reflection have helped to inform future delivery of LCA methodology and embed this in further projects. An improved tool set is planned to be adopted to eliminate the interactive updates we had to undertake due to the nature of the data set and manual access to the excel spreadsheet. Further academic training is planned for the new toolset which will embed this further into our other course structures and projects; driving design through improvements in carbon foot printing will become embedded across multiple product design pathways and further sharing learning across departments as the tools set becomes embedded.

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HOW DO YOU FEEL? EMOTIONAL WELLBEING IN DISTRIBUTED LEARNING ENVIRONMENTS IN DESIGN STUDIES

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ABSTRACT
This study analyses emotional wellbeing and the learning process of design students in a globally distributed learning environment. Currently students are known for their capabilities to find information, to learn and think, to socialize and to behave in a global network, but difficulties operating in a distributed product development process have emerged.
Global co-habituation and other user-generated internet content have helped to connect student partner teams in different time zones and cultures but have raised questions of learning practices within pluralistic and virtual learning environment in design studies.
Uncertainty of design process, tackling outcomes from each of the design phase that were informing the subsequent design stage and performing from two different ‘personas’ (the client and the designer) by not knowing prior which role to take, has contributed to emotional ill-being amongst students. During the learning process via distributed product development students were constantly surveyed and questioned to understand how they felt and what was their emotional wellbeing point in a learning ecosystem which they experienced and practiced for the first time.
The analysis of the learning process outlines that it is crucial to have supportive and enabling technologies and lecturers for virtual learning to create a positive learning experience. The learning process aimed to enable students to work successfully with various organisational members in the distributed product development process while emotional underpinning of the learning trough design process was described as frustrating and confusing.

Keywords: Design pedagogy, distributed learning environment, emotional wellbeing

1 TEACHING-LEARNING THEORIES BEHIND DISTRIBUTED LEARNING ENVIRONMENTS IN DESIGN STUDIES

The design process as a teaching - learning methodology involves authentic experiences inherent in the community and a critical reflection of context and culture. There are several teaching-learning theories that reflect design process and design studies. Constructivism emphasizes that students have to actively construct understanding from different sources and emphasizes exploration of learning by doing, thinking and connecting ideas in a meaningful context. [1] It also suggests that the implication of learning experiences needs to be culturally and contextually authentic. [2]
Design process as a hands-on teaching paradigm is closely linked with situated cognition [3] where learning a subject is a process of becoming a member of that subject's community. Situated cognition when ‘learners’ participate in real-world contexts is embedded in human-centred and ethnographic studies of design projects and research. Design research and product-service development are based on social constructivist theory. The focus and design context are based on socio-cultural factors, growing or developing ourselves and our society in certain (connected) ways. [4] As an active engagement design process reflects connectivism [5] – i.e., activities that are undertaken when we conduct practices to learn.
Distributed learning environment (DLE) is characterized by independent learning over time and place: learners are “distributed” or separated by geography, technology, experience, and people. [6] The main components of DLE are learned and practiced in small increments or over several spaced sessions, that in this case study reflects learning through design process. Distributed practice claims to help in recalling information over longer periods of time and to activate contextual memory. [7] Overall DLE emphasize

the importance of learner-centred, collaborative and network approaches and provides students with the flexibility and autonomy to construct their own learning experience while also offering opportunities for socialization, feedback, and reflection. [8]

Current students are representing Generation Z (Gen Z). As digital natives they prefer intrapersonal or solitary learning as a backup to using technology. [9] The post-millennium period created a shift in culture and behaviour and Gen Z is known of their capabilities to find information, to learn and think, to socialize and to behave in a global network. [10] Their individual learning differs radically from the teamwork-oriented and collaborative nature of Millennials. Gen Z need time for individual learning and reflection before group work or Think-Pair-Share processes. [11] They value peers and instructors as learning resources only after thinking through a concept, problem, or project on their own, and the content they are learning needs to be applicable beyond just a single practice. [12] However "around a third of university students struggle to learn independently" [13] and have emotional and mental difficulties. Emotional wellbeing is a crucial factor in the teaching-learning process and significantly impacts academic success [14] and personal development of students [15].

The twenty-first century is marked from other eras through the incredible power of technology, not by the need to develop important skills such as problem-solving, creative thinking, critical thinking, and relating to people [16] as foundations for emotional wellbeing. Design creates happiness and satisfaction as an end-result in the products and services we use [17], and so should education as a learning and teaching process. It is important to engage not just all senses in the learning process according to cognitivist theory, but also to build emotional connections. [18] It is about connecting teams, peers, even students, with emotions, not task-focused automatons, says Edinger. The emotional connections made through mentoring and coaching, and the lecturers' 'interest in students' professional growth, pay off in the long term for both parties. [19] Investing time and resources in students' development, coaching and mentoring, allows them to feel more engaged in their work, increases their confidence, and ultimately improves their performance.

"How do you feel?" aims to reveal the invisibly visible emotional wellbeing during DLE in design and questions; 'What should design lecturers address for better learning experience for Gen Z students?

2 GLOBALLY DISTRIBUTED LEARNING – TEACHING ENVIRONMENT: PROCESS, PROS & CONS AND IMPACTS

Teaching-learning experience models, based on design process, constructivism, situated cognition and connectivism, when knowledge is constructed by the individual and their experience in the world, was behind global DLE in design studies analysed in this paper. Students were surveyed three times via Vevox platform during twelve-week module, questioned and observed to comprehend what their emotional wellbeing and the learning progress is. For the case study eleven student responses were analysed.

Each study week as learning phase corresponded to a particular stage in the design process such as: Exploration (1), Design Brief (2), Design Brief Evaluation (3), Concept Design (4), Concept Evaluation (5), Design Concepts Refinement (6), Detail Design (7), Prototyping (8), Testing (9) and Design Evaluation (10), and outcomes from each of the phases informed the subsequent design phase of the projects over one semester's 12-week learning-teaching process. Students were divided into teams (three students per team) and paired with international student teams from four countries. To address given assignment students had to act from two different 'personas' – the client and the designer, and to work across different cultures and time zones in Europe and Asia. If one team was not performing on time and not delivering output weekly, the partner team could not progress.

Initially students were not instructed in which phase (Figure 1) they had to act as clients (phases 1; 2; 5; 9; 10) or designers (3; 4; 6; 7; 8). Phases 1 and 9 asked students to become a member of subject's community and be involved in authentic experience as a critical reflection of context and culture.

The assignment was managed by international lecturers from six countries and led by studio X (anonymised). To respect partner universities, it was decided not to reveal the institutions identities. However, the module was delivered according to the ethical guidelines of the academic practice.

By agreeing to be part of an international, collaborative design assignment, I was briefed not to reveal the prior design process - in which persona and why students have to behave. Students were supposed to find out themselves in which role every week are they performing. To communicate, to monitor the progress of given assignment, collaborate, reflect and to give feedback, an online WordPress blog page was created with each team member given individual access.

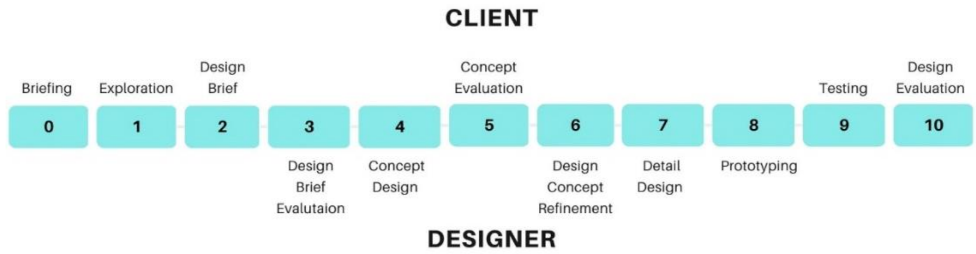

Figure 1. Learning trough design process in DLE, Freimane, 2023

Students were not briefed that the module was not only based on authentic situation-assessment [20] and product development across distributed environments but also on developing students' transversal skills [21]. It was supposed that students would discover and understand the learning outcomes by themselves during the DLE process in design studies.

2.1 Uncertainty of design and learning process – pros for emotional ill-being

Uncertainty is an inherent part of the design process, and it can be both exciting and tough for designers to navigate a range of different challenges and obstacles in order to arrive at a successful outcome. Designers, including students, experience a range of emotions throughout the design process, including excitement, anxiety, and frustration, as they navigate the uncertainties and challenges of the process. [22] In this case study not only design process – as design for the result was confusing but also the learning process as it was not revealed from the very beginning. In spite that Gen Z students are digital natives and are accustomed of using technology to access and process an information, limited access to materials, lack of face-to-face feedback, communication challenges, technical issues and limited collaboration opportunities in DLE created additional uncertainty and frustration from the very first day. Yet that design studies were planned to be delivered online as DLE, I decided to hold weekly teaching sessions in person: the University had a requirement for in-person classes as a return to campus policy after Covid-19 break.

Some direct quotes from students surveyed during the process: on the assignment and the study process after the first three design phases, revealed: "*I found the tasks confusing"; "We received very vague information in terms of what the process and content of creating the brief was, so it was very difficult to complete"; "Not many guidelines on how to provide a brief. Just felt really confused all the time. I was often left asking other students in the class about the work we were meant to be doing. Every so often I did not understand why we're doing what we were doing. These issues were eventually figured out but took time away from the actual work we were meant to complete*."

It was easy to sense the students' frustration and anxiety through the face-to-face meetings. They were also asking for certainty in the teaching-learning process. As a result, I decided to reveal every learning phase and design process and to make it clear and explicit not only verbally but also visually (Figure 1). I marked the phase as a milestone and the role in which students should act for the upcoming week in relation to the whole design process. In that way I reflected Gen Z's need to know what and why they are doing and supported their emotional wellbeing.

As a take-away it is essential that lecturers provide clear guidelines, communication channels, and feedback opportunities to help students navigate the uncertainty of the design and learning process effectively. It is even more important for Gen Z students as they need to know what and why are they studying and where can they apply their acquired knowledge and skillsets.

Lockdown and remote learning during the Covid-19 Pandemic as recent experiences have taught us how to collaborate and study online. It might be obvious that students are capable and willing to continue in distance education, but does that process favour opportunities for socialization, receiving feedback and reflection from lecturers and peers, as technologies and distributed peers are invisible, even in different time zones and sometime have limited knowledge of English language? These are the critical questions. It highlights that collaborative online platforms need to be perceivable, intelligible, and experienceable [23] not to burden both learning and teaching process technology-wise and administratively.

Need for understandable, intuitive, logical technologies was mentioned by students: "W*e have to use the Studio X platform, but it is such a bad and difficult website to use. It is very confusing and difficult to set up, navigate and understand. There were many technical difficulties that prevented me from using the online recourses, so it was quite frustrating."*

Handling uncertainties of design and learning process as well as technological issues highlights the need for "*more casual way to communicate and easy to share Q&A that saves more time.*" Students found their way to communicate but that gave an impact on overall visibility of what was happening behind the screen and how to be sure that the learning process happens.
Neither design process nor DLE reflected Gen Z need to have time for intrapersonal or solitary learning and reflection before group work or Think-Pair-Share processes. It might be considerable to iterate some design phases and not to run over design process every week. Students reflected that they "*felt very lost and confused because we were never taught how to write a brief*", for example.

2.2 Responsibility, time management and tolerance – pros for successful collaboration and teamwork

Teamwork, collaboration, and people are crucial aspects in the design process and DLE. It can be challenging to sustain the emotional connections between lecturer and students, to perform independent learning, to build trust and establish strong working relationships when working with colleagues who are geographically distant over time and place. Building trust in distributed teams requires a high level of communication, transparency, and shared understanding of goals and expectations [24], empathy and responsibility towards peers.
Distributed teams can experience social isolation and lack of camaraderie, responsibility towards teammates and partner teams, and even towards deliverables. Students acknowledged that it was "*hard to communicate due to time differences and schedule differences. It's definitely different when you come with online and in-person conversation, especially with the role of clients and designer*." Analysis of the learning process revealed the need for teaching and practice in asking questions and discuss, and to accept other person's point of view; "*the most dissatisfying was trying to communicate with the other team and them saying we can't do this we can't do that even though the brief says so. The collaborating group deciding to not participate in our brief and not communicate with us*."
The theory said that the lecturers' interest in students' growth, coaching and mentoring, allows students to feel more engaged in their work, increases their confidence, and ultimately improves their performance. Lecturers should be mindful in their communication and understand cultural differences as much as students to create an emotional connection and wellbeing which is a critical factor in the teaching-learning process. The feedback given by students indicated that not only uncertainty of the given assignment and used technologies, but also the tone and voice of coaching impacted student emotional wellbeing: *"Lecturer was consistently extremely rude and abrupt during online classes. He would always talk over, interrupt other lecturers and students. He did not allow us to properly communicate and left many students unwilling to speak to him or even turn up to the online class. He created a very uncomfortable environment."* Overall, the emotional experience of learners is an important consideration in the design of DLE in design studies. By addressing the challenges of isolation and disconnection, and employing strategies to improve learner motivation and engagement, lecturers can create environments that support positive learning outcomes.
The analysis of students' feedback revealed the visible emotional wellbeing in design studies and answered the question on what should design instructors address for better learning experience for Gen Z students. However, learning-teaching process is two dimensional and the question – what impacts lecturer emotional wellbeing within DLE and international online collaboration - is still opened and unrevealed.

2.3 How do you feel – an effect of distributed learning environment in design studies

The emotional experience of learners can have a significant impact on learning outcomes under DLE, including those in design studies. A range of factors, such as feelings of isolation, frustration, and disengagement, can negatively impact learner motivation and engagement, and ultimately impact learning outcomes.
At the end of the module students were surveyed the third time to capture the progresses of independent learning over time and place. Some students acknowledged that "*I have not experienced much during this module besides stress and confusion*" and "*due to issues already stated it was difficult to learn about other culture issues and concepts*." In spite of emotional ill-being throughout the module some students admitted; "*I'd say that this experience would be the benefit for us as design student*."
As students were not briefed on the module aims and learning outcomes, but were supposed to discover it by themselves, it was essential to find their take-away. Multiple answers on what was the aim of the

module were available. The least popular answer was to enjoy the process (63%). Also, 91% of students noted that the aim the module was to learn and tolerate cultural differences, learn to be responsible of team member's time, practice to write design brief and to gain skills to work with various organizational members. 82% admitted that the aim was to practice design research and to learn about design process whereas 73% acknowledged that the study aim was to learn to ask questions and respond, and to gain skills to work in the distributed product development environment.
100% of students acknowledged that communications skills were the most important competencies from the range of transversal skills they learned during this module. It indicates that design studies through DLE is more about communication than creativity, which was mentioned only by 50% students. 70% of students identified critical thinking, teamwork, conflict resolution and collaboration whereas no one recognized that media and information literacy should be taught in design process trough DLE. However, it is possible to analyse only a short-term effect on the design studies trough DLE.

Figure 2. Survey results on the aim and learning outcomes of the DLE module, Freimane, 2023

Students when asked about the most satisfying aspect of this module named the final presentation of their work and feedback from their partner team as key: "*We have learned a lot of skills and experience through this project, specially understanding the position between as client and designer.*" Asked what students will remember the most from this module, as a positive take-away, they highlighted "*designing progress of our product; the importance of understanding and researching political and cultural differences when working internationally; and speaking to our lecturer about various cultures and how to tolerate everyone and be better, and also all of the beneficial skills in conflict resolution, which was great*!" As a negative students commented on some lecturers "*being rude and the other team not cooperating*". However, they "*did learn a lot about time management and communication*." In short, students acknowledged "*the task was a good learning experience*."

3 CONCLUSIONS

Also, students admitted that they learned a lot during the module and the international collaboration, that they never ever before experienced authentic assignment-assessment, and the task was not easy but engaging. Even in student-led learning paradigms they have to construct understanding from different sources, explore learning by doing, connecting ideas in a context, it is essential that lecturers minimize uncertainties and provide clear guidelines on what and why students are studying and where can they apply acquired knowledge and skillsets. To decrease ambiguities by providing communication channels, and feedback opportunities in person would help students navigate the uncertainty of the design and learning process, something that is centrally important for Gen Z students.
Lectures and administrative staff should ensure that technologies and digital communication platforms are supportive and user-friendly. DLE should facilitate the learning process with all involved parties explicitly visible. Lecturers should consider that Gen Z need time for intrapersonal or solitary learning and reflection before group work or Think-Pair-Share activities.
An emotional connection and wellbeing, the tone and voice of coaching are critical factors in the teaching-learning process for both students and lecturers. The case study analysis revealed the invisibly visible emotional wellbeing in design studies and identified what design should lecturers address for better learning experience for Gen Z students. Is it possible to increase enjoyability of the study process at least to 99%? This should be the research question for the next case study.
Nevertheless, the learning-teaching process impacts not only students but also lecturers' emotional wellbeing. Lecturers can deliver the subject professionally, address the inclusive needs of students, be empathic and student-user-centred, to be student-centred, empathetic and tolerate non-attendance of lectures, manage administrative process that DLE runs fluent. But ultimately, no one asks and assists when the lecturer's personal health, emotional wellbeing become strained and fragile.

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CREATING A MODULE TO EMPOWER ENGINEERING STUDENTS TO BECOME CHAMPIONS FOR EQUALITY, DIVERSITY AND INCLUSION

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ABSTRACT
This paper describes the creation of an optional third and fourth year module for the Mechanical Engineering undergraduate degree course at Imperial College London through a student-staff co-creation partnership. The module was designed to empower students taking the module, to become champions for equality, diversity, and inclusion (EDI) and to subsequently play a key role in systematically improving EDI in the engineering industry. The process described here provides an exemplar for other institutions to follow. The initial module design was developed through liaison with academics with EDI expertise, outreach charities and relevant teams within Imperial College London. The aims of the module were to enable students to think in the context of global society, develop an appreciation for EDI issues, and gain experience in initiative design to improve EDI in engineering.
The outcomes of the student project to develop a proposal for this module included a justification for implementation, proposed syllabus and assessments. The module was subsequently implemented with modifications to the initial proposal for logistical, financial, and pedagogical reasons. Although several other departments and institutions have created modules attempting to address EDI issues through societal engagement or design, this module's concerted focus on empowering students to become EDI champions in engineering makes it one of the first of its kind offered as part of an engineering degree in the UK. By detailing the process of creating this module at this conference, we hope to inspire and serve as a springboard for the creation of similar modules in other university engineering courses.

Keywords: Equality, diversity, inclusion, module design, co-creation

1 INTRODUCTION
The state of EDI in the engineering industry is troubling. The UK has the lowest proportion of female engineers in Europe at just 8%. The Royal Academy of Engineering reports that although 26% of engineering students identify as BAME, only 6% of professional engineers are non-white [1]. Statistics such as these lead students to feel that the industry lacks sufficient understanding and prioritisation of EDI issues, despite UK chartership competencies requiring engineers to understand diversity and equality issues [3]. Galvanised by the 2020 Black Lives Matter protests, students from the Mechanical Engineering Department at Imperial College London, including authors of this paper, wrote an open letter in their university's newspaper inviting the department to adopt several specific EDI-improvement measures. The ensuing discourse between staff and students led three students to propose an elective module; EDI in engineering. The module provided a means of bridging the aforementioned gap and empowering participants to affect change as graduates in the engineering sector. To achieve this end a 10-week departmentally funded project to design the EDI module was conducted in the summer of 2021, with staff supervisors working in collaboration with student partners. The students researched and designed the following aspects of the module: aims and objectives; curriculum and seminar topics; timeline and structure; and assessment methods. A report was written at the end of the summer project summarising the work undertaken. This report was used as a basis to gain approval for implementation. The module commenced in the 2022-23 academic year with some modifications to the original proposal made for practical and pedagogic reasons.

2 METHODOLOGIES

This section outlines the steps taken by the students during the summer project to develop this module. The project structure began with a knowledge collecting phase, then a design phase, and finally a feedback and iteration phase.

2.1 Research

Research consisted of three parts: (i) understanding the current state of EDI within the engineering industry as published in the literature, including existing EDI initiatives; (ii) reviewing existing modules within Imperial that applied EDI concepts to STEM subjects; and (iii) reviewing how EDI topics were taught in higher education more broadly. A literature review was written, compiling information from 32 EDI reports, papers and toolkits. This began with surveying reports published by Advance HE and The Sutton Trust and McKinsey [4] [5] [6]. The aim of the review was to answer several questions: what factors contribute to a consistent lack of diversity in the industry; why are current forms of outreach not working; what are the suggested avenues for improvement? IMechE key competencies for accreditation were also reviewed, in particular the requirement to understand equality and diversity. This review, along with evidence of other successful EDI-focused university initiatives, provided a strong case for implementation of such a module.

To research existing EDI-focused education both within STEM departments at Imperial, and within higher education at some other UK universities, the student authors spoke directly with those involved in relevant EDI initiatives, research and/ or education. Initial conversations led to engagement with a broader range of contacts within the field to speak with, including with non-STEM related specialisms (including politics, sociology, psychology, anthropology, economics, history, design, business). Speaking with experts not only inspired module content, but also led to invitations for guest lecturers for the module; module participants therefore benefitting from listening directly to experts and specialists in the field.

2.2 Designing Aims and Objectives

When designing the module syllabus, dialogue between students and staff was frequent and essential. Staff provided information on the processes to be followed for a new module to be approved, such as a module descriptor, including aims and objectives, structure and content, and assessment methods. The detailed module aims and objectives were based in a large part on the lived experiences of the student module designers and their departmental peers. Using resources from the Imperial Educational Development Unit, including guidance on writing module aims and objectives, students were able to write aims and objectives in their own words which would meet the requirements for module approval. Research described above also influenced the choice of aims and objectives. The module aims and objectives are shown below and influenced all other stages of curriculum design;

2.2.1 Aims

- This module will encourage students to critically think about and proactively engage with engineering in the context of global society.
- The module will develop students' appreciation and understanding of equality, diversity, and inclusion (EDI) within the engineering industry, as demanded by the IMechE Engineering Chartership.
- Students will gain practical experience of initiative coordination, allowing them to champion better EDI as well as improving interpersonal skills.

2.2.2 Learning Objectives

- Define EDI and provide an overview of its status in engineering.
- Present the importance of EDI in engineering & the positive impact of widening participation.
- Present the barriers to better EDI in engineering and the obstacles to removing these barriers.
- Present EDI consideration through engineering with a more accessible, empathetic, and inclusive approach to engineering design.
- Present the effective design of a positive EDI initiative.
- Develop critical analysis and evaluation skills with regards to EDI initiatives.
- Develop communication & interpersonal skills in discussing, planning & actioning initiatives.
- Develop data gathering skills to classify the impact of initiatives.

- Facilitate reflexive practice regarding EDI in engineering.

2.3 Determining Module Content

Following the research stage, student designers and supervising staff were all keen to ensure that content was delivered by experts. Student partners identified key topics to be covered and appropriate experts to approach. Staff and students discussed what information experts may need to help them make a decision as to whether they could participate, including e.g., delivery mode, content area, time commitment (the initial expectation being that guests would participate on a voluntary basis). Students led on developing content scope and curating a list of seminar/lecture topics to include in the module.

As design teaching forms a significant component of the degree, the initial proposal included discussion on accessible design to encourage students to use learning from the EDI module in their degree. In terms of structure, the proposal was to split the module into a series of seminars/lectures in the Autumn term, followed by project work in the Spring term. This choice was based on very similar structures in existing modules within the department; consideration was given to assessment timings to avoid busy assessment periods for students.

2.4 Initial Assessment Design

The importance of constructive alignment [7] between module objectives and assessments was emphasised in staff-student discussion. The initial assessment deliverables proposed were as follows (weightings given in brackets): a reflective/reflexive logbook (25%), an individual task to promote/improve EDI within the department (10%), a group project to design and implement an EDI-focused initiative (45%), and a conduct of task mark including peer assessment (20%). The tasks and weightings of the initial assessment design are typical of other coursework-based modules within the department. For the group project section of the assessment, example initiatives proposed included: an online engineering outreach event for autistic students; creating a toolkit for lecturers within the Mechanical Engineering department to use when embedding EDI into their courses; designing and implementing a reverse mentoring scheme within the department.

Of particular note is the reflective/reflexive logbook. This format was chosen as being familiar to students on the course as they are taught to use project logbooks to record progress from their first year of studies. The decision to make this reflexive was based on discussions with the programme lead for the International Inequalities Institute. Reflexive practice is an extension of reflective practice in which the practitioner, in addition to observing their reaction to a situation, also identifies their role within the context of the situation and understands that this will influence their interaction [8]. The choice to include this extension of critical thinking was to enable students to extend their learning from EDI issues within wider society, to identifying their role in society and how this in turn can affect the EDI issues an individual observes (and in particular, their role and influence within the engineering industry).

2.5 Student Body Feedback to Proposal

The student module proposal was well received by staff. Surveys were also conducted to identify whether the general student body also felt the proposed module was needed to fill a learning gap in the Mechanical Engineering degree course. The results formed a valuable basis by which the need for the module was justified in a presentation to the department at the end of the project. The surveys were sent out by the student authors via conventional e-mail channels, as well as through personal networks, reaching out directly to students and alumni. When interpreting the qualitative survey results the student authors were able to contextualise critiques and comments from their experience as fellow students and addressed them through design developments. The key conclusions from the survey results provided support for its adoption, and can be summarised as follows:

- A disconnect was identified between student's desire for more EDI in engineering and their ability to act on this due to a lack of structure and available time. The EDI module provides both structure, and time within the student workload and schedule for this learning.
- Under-represented students in general, had not been participants in targeted engineering outreach in the past, showing a lack of EDI initiatives in engineering. The EDI module is a form of outreach itself but will also generate EDI initiatives for future implementation.
- Non-underrepresented students were less interested in learning about EDI and less likely to see it as important than underrepresented students but were equally confident in discussing the topic

and so were potentially overconfident in discussing EDI issues. Positionality education within the module would address this.

- When alumni were asked how they felt the degree course developed a range of key skills related to chartership competencies and employability, they rated empathy the lowest. In improving understanding of EDI in engineering and allowing students to engage with it through planning collaborative initiatives, it is hoped that the proposed module will place a heavy emphasis on the development of empathy skills [9].

2.6 Staff Proposal Feedback and Changes to Module

The module proposal was presented to the Equality, Diversity, Departmental Culture Committee (EDDCC) and Courses Committee (CC) and accepted for implementation. There were a number of changes made to the initial proposal before implementation for pedagogic reasons. These changes focused on initiative implementation, peer assessment and overall assessment content. The initial proposal for the module included implementation of a group EDI initiative and the grade for this included evaluation of the initiative by outside participants. This meant grades would be dependent on third parties. It would also have been difficult to implement such an initiative within an 11-week term. To address these issues, the group project was changed to include development of initiative design, evaluation and communication strategy, but removing implementation. After assessment students would be supported to implement their initiatives if they wish. The initial proposal also included assessment of team member's group input (peer review); however, peer review is known to be subject to unconscious bias [2] and thus may disproportionately negatively impact marginalised students. As such, the summative peer review was replaced with a formative one. This formative peer review now forms the basis for a reflective essay in which students write about their role in the project team, their personal development journey and how this has been impacted by positionality. In the overall assessment, two smaller elements were removed to reduce student workload, enabling the initiative design to be given greater credit. This also allowed for the removal of a "conduct of task" element which can also be subject to unconscious bias.

3 RESULT OF MODULE DEVELOPMENT

The module began as a pilot in October 2022, with the module running over Autumn and Spring term. 24 students enrolled, which was considered to be a reasonable number for a pilot module (a maximum number of 30 had been set). Attendance has been on average proportionately higher than other optional modules at this level, with high levels of engagement as measured by in class discussion. There have been challenges in sourcing expert lecturers from within engineering to match all the proposed topics. Whilst speakers were identified for this pilot module from within Imperial, other HEIs, industry and EDI consultancies, we are looking to supplement, replace, film and or train these in order to enhance the quality of the lectures. Running the course has been beneficial for all involved as the level of staff learning about the expert topics, in addition to the student learning has been noticeable, leading to adaptations to teaching and other processes throughout the department. The lectures themselves, which were engaging and provided key content often occupied much of the allocated timetabled hours; there may be scope in the future to increase the time available for discussion and reflection in the first term. The plan is to continue the module within the department next year. We will also either invite students from other departments to join us or to support other departments, many of whom have already expressed an interest in the module, in running their own version of it. We are also supporting other universities with a similar interest.

The syllabus for the module can be found on the Mechanical Engineering Department page of the Imperial College website, under Undergraduate Study; Detailed Module Information; Year 3; Equality Diversity and Inclusion in Engineering (https://www.imperial.ac.uk/mechanical-engineering/study/undergraduate/detailed-module-information/?module=MECH60025&year=22_23).

4 DISCUSSIONS

We consider that the summer project to develop the EDI module was a success. A few key factors contributed toward this. Firstly, a passion driven approach was taken, as the authors all have a desire to improve the experience in engineering for underrepresented groups with whom we identify, and beyond. This was demonstrated in the interview process when the student authors approached EDI experts and were able to break down unnecessary formalisms to allow for passion-led discussion, facilitating lateral creative thinking. Interviews led to breakthroughs in module design and enabled the team to grow a powerful EDI-network for use during the module. Secondly, because the project was entirely self-proposed and self-managed there was freedom to determine which direction module development would take, as appropriate. This allowed for transparent and easy communication between student authors and staff. The role of staff in this was centred on signposting resources, providing an educator's perspective, and supporting during ideation. This co-creative approach allowed for innovative module design, without the need to adhere to standard engineering module design practices.

There are a few areas where future student-staff collaborations could be improved, particularly for EDI related initiatives. The funding for this project was through a standard UROP (undergraduate research opportunity) bursary. This bursary is not based on an hourly rate and there are no fixed set hours. It is suggested here that an alternative funding mechanism should be based on an hourly rate, to ensure students are fully funded for all hours spent or that alternative sources of funding are sought. On reflection, it may have been useful to hold focus groups with students when collecting views on the introduction of an EDI module, instead of or in addition to surveys to allow more detailed analysis of responses. The design and implementation of the module relied heavily on input from minoritized groups. It should be acknowledged that often the burden of diversity and inclusion work often falls on those in oppressed groups. This was particularly evident when interviewing EDI initiators in the engineering industry or at HEIs who felt at times they were taking on work that was not part of their job description, at the detriment to their career. There was a delay between proposing the implementation of this module and the implementation itself; there were a number of reasons for this. Firstly, the timing of the project itself and the time scales for approving new modules. Secondly, changes in staffing meant that a module lead was not immediately available. The eventual module lead was also not directly involved with the initial design, and some changes were made in module content and design to take into account the module lead's areas of expertise. One of the initial project staff partners was able to take on the role as associate module lead ensuring continuity from module initiation to implementation. On reflection, it may have been useful to include in the module design proposal what aspects students felt were essential and what parts they felt were not. This allows for a continuation of the student-staff co-creative process even after handover.

The project has had a major impact on subsequent EDI development for the student authors. Following the summer project and after graduating, these students wished to continue EDI work in an industry environment. One student became involved in several initiatives at their company, including founding their own ethnic minority network and running a series of inclusive design workshops. Another student joined several employee resource groups to do with diversity inclusion and belonging at their company. They have developed a scheme that helps line managers have more productive and actionable conversations with employees about DIB issues.

5 CONCLUSIONS

In response to the student and staff desire for mechanical engineering students to have a positive impact on EDI in engineering, an optional module 'Equality, Diversity and Inclusivity in Engineering' was designed and implemented through a successful co-creation project. The design phase was funded through a departmental bursary and took place over 10 weeks in summer 2021. The design phase included extensive research and discussions with both internal and external EDI experts. The module syllabus and assessment methods proposed by students were written up in a report and approved by the department for implementation. Some minor changes, primarily to coursework and assessment elements were made for pedagogic and practical reasons. The module began being taught as a pilot in October 2022; the first term being lecture based and the second term being focused on the design of an EDI in engineering initiative. The assessments include bi-weekly initiative-based tasks, a curated logbook and reflective essay. Engagement and student progress have so far been encouraging and the module will be offered again next academic year. The success of this project is a result of strong student staff partnership and the direct and personal experiences of the student partners, as well as broader interest from within the UK higher education sector.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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DATA AND PRODUCT DEVELOPMENT: THE NEED FOR A DATA PRACTICE PARADIGM IN DESIGN EDUCATION, A PROJECT-BASED REFLECTION ON USING MATLAB SOFTWARE FOR SENSOR DATA CAPTURE AND ANALYSIS

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ABSTRACT
This paper discusses how MATLAB software was integrated into the research and design process by capturing and visualising data to inform a 4th-year capstone undergraduate industrial design product development project. Examined within the project framework are perspectives on; data use for design projects from the literature, data collection, understanding project data, designer alternate skill set, using data to justify design direction, associated data capture technologies, data-driven changes of state for UIs (User Interface) and a proposal that designers need to have a data practice paradigm. As technology rapidly embeds into almost every aspect of society data is produced and captured at a diversity and scale previously unparalleled. Tools and systems to capture and assess such data simultaneously are being democratised, bringing new understandings and accessibility to systems for testing hypotheses more efficiently, either with sensor-based open-source hardware microprocessors or commercial data capturing systems. Designers developing smart products, smart system proposals, and IoT devices need to integrate these data capture and assessment tools into traditional product development and research processes. This is especially significant in projects where subtle technical innovation and application of new technologies, “technology epiphanies”[9], or natural user interfaces (NUI) are present. These themes are critical to designers at present; engineers, data scientists and computing scientists apply data analysis techniques to design problems previously in the product designer’s training skillset. Having an applied understanding of such processes would permit designers to regain control over domains slipping into the grasp of allied product development disciplines.

Keywords: Data, MATLAB, Simulink, user interface, UI, TUI, NUI, IoT product development, control systems, Arduino

1 INTRODUCTION
As products become more connected and digital, and as machine learning creates new interactions to collected data, designers need to understand how this data is appropriately collected and utilised and how this can augment their conceptual thinking around solutions. A discipline specific data practice paradigm for undergraduate students needs to be developed around quantitative data; currently the waters are murky for product design concerning data practices. We can learn pre-existing processes from our colleagues in the computing and hard sciences. However, a defined flexible model suitable for design is needed, a carbon copy is inappropriate. Qualitative research methods taught in undergraduate programs suit many design problems and practices but not all. The diversity of projects and evolving practices in the industry around quantitative data needs attention. For example, final year undergraduate product design major research projects take many forms, from highly conceptual to incremental innovation, highly technical to low technical, form-driven to function-driven, research-driven to development-driven, market-ready to crude conceptual mock-up, degree programs assessing an equal balance or varying degrees of each distinction. Nuances between product and industrial design programs and school to school, guide where the focus may be. All programs, however, strive to get a well-balanced demonstration of prior learning in a focused project. What is needed to meet future challenges of designing products is working with quantitative data, "With data and machine intelligence being the

design material of the future..", [13]. Some experience using data on at least one part of a major design project is essential for young designers, no matter the type of project. For example, collecting Tall-Data or Fat-Data, rather than qualitative Thick-data on an existing product's performance may help young designers conceptualise how their product may function better, or be augmented with real-time machine learning, thereby enriching design concepts beyond non-smart products.

2 DATA USE IN DESIGN TO REDUCE ASSUMPTIONS

Reducing subjective assumptions from the product design process, especially at the front end of a project, allows deeper reflection of functionality or feature design in the backend. As discussed above by Hou, Liang & Jiao, data can be accumulated at multiple points in the lifecycle of a product as well as multiple points in the product development phases. Professional designers, let alone undergraduate students completing major product design projects, cannot verify all aspects of their design decisions with data or even literature research. Ideally, data-guided research should be used for at least one of the product development activities in the product development cycle.

2.1 Product feedback loop

The UX interaction community and TUI discipline use a data-driven feedback loop [13]. This data-driven feedback loop drives concept testing and adaptation. There are highly polished UX research project process examples, however these examples tend to have a simple design aesthetic and focus on interaction rather than the well-designed physical object. They spend more time prototyping the interaction and creating a feedback loop, whereas product designers focus on the object and simulate how the product will be used or interacted with. Combining both methods, a polished visual design and a polished interaction are ideal. One sees a push to necessitate this data-driven-feedback loop within product design schools. However, as discussed above, this is logistically difficult due to the scale of undergraduate product design projects. There is tension and competition between UX computing and design disciplines, computing scientists relying on data to design and designers relying more on experienced-based intuition. Historically, designers are focused on non-smart products, lifeless non-digital products that are continuously commoditised to the point of disinterest to the public view, and therefore a shrinking new product development area. The generally more interesting design projects blend the two methods. It could be argued that a designer with data capture and development skills using data-guided intuition, not just 'intuition'[2], would be better placed to develop projects with greater projected vision. In product design, where the problem or requirements are not necessarily apparent, or "the client's brief will be vague, it is only by the designer suggesting possible solutions that the client's requirements and criteria become clear." [2]. Moving into the future, student product designers with experience using quantitative data somewhere in the 'data loop' will gain deeper insights into product development previously inaccessible or, from a practical perspective too challenging to complete.

2.2 Data capture practices vary across disciplines

Design problems and projects are varied and so, too, are the types of data required to considerately propose an effective solution. Where a student project starts, either at the defining of the problem phase or after the problem has been clearly defined, this influences the approach to a project and, therefore, what type of data is to be collected or assessed in the investigation or validation phases. Many factors influence the design process research strategy and therefore data collection methods, however, clear research paths have been established in the sciences with a long history of the scientific method defined. From the onset, students receive a clearly defined investigation, with clearly defined research processes, and therefore have a ‘hit the ground running’ approach to data capture and evaluation. Design projects are different, problem-identification and problem-solving approaches are diverse. The value of a designer is not in the pre-set design project with pre-set methods and a closed brief. Design thinking training is about approaching problems without a pre-set strategy. The ‘wicked problems’ and the ill-defined is where designers’ skills are valued, pre-setting all aspects of a design project reduces the student training in defining a project with ‘appropriate to the project methods’, whatever they may end up being. As discussed by Pavliviscak in 2015, "There is a lot of hype about data-driven or data-informed design, but there is very little agreement about what it really means"[11], 'Big-data' defines large data sets, 'thick-data' ethnographic interviews and surveys. Big data is further apportioned into; "Tall Data where the number of observations is large, and Fat Data where the number of variables is large”[7]. Scientific engineering data approaches to problem-solving tend to be "theory-based models, these encapsulate cause-effect relationships between variables that have either been empirically proven or theoretically deduced from first principles."[6]. Essentially data is collected between small changes in variables within designed experiments, a ‘Black Box’ approach to deduce performance. This “engineering design process generally encompasses; the requirement analysis, conceptual design, embodiment design, and detailed design phases, which is enacted through a cascading mapping of design decisions regarding customer needs, functional requirements, product architecture, and the end-product specifications”. [14] Big data is often collected without a goal or experiment in mind, [6] and analysed to identify insights or patterns. Blended or hybrid approaches such as “Theory-Guided Data Science”[6] and ‘big-thick blending’, as Bornakke & Due discuss in their 2018 article, *Methodologies in how to approach blending data sets,* suggests the requirement of data analysis expertise across data analysis disciplines. Bornakke & Due conclude their article by stating, "Blending thus joins with the growing choir of digital-based scholars who suggest that social scientists abandon the historical ideal of the renaissance person, bound to the individual but genius scholar who masters all methods" [1]. This statement was made without even including engineering theory-based data collection methods. This highlights the challenge of data collection for design projects, and what data collection and analysis methods should be used for design projects, or, more importantly, what methods we utilise when training and testing our undergraduate designers. This highly multifaceted methodological decision needs some form of resolution if product design degrees are to stay competitive or relevant as HCI computing graduates take on traditionally held product design ground. Adding; quantitative data capture, data analysis or data responsive design to at least one phase of the design process in undergraduate product design courses would help designers stay relevant. One trialled approach, to be discussed below, is the capturing of scientific engineering variable data, which, for undergraduate projects, may prove appropriate. Using a loose engineering method, it was possible to identify variance in the data, this guided project parameters and added a level of quantum to the project. Moreover, like many student design projects, completing all aspects of a design project, essentially producing market-ready products, is unrealistic due to time, money and infrastructure. However, like the theoretical building blocks of scientific knowledge, the 'yes I think this is feasible' building blocks of a product design project can be fortified with data, thus improving design project justification whilst at the same time preparing undergraduate students to gain rather than lose ground to allied disciplines in the competitive world of new product development.

2.3 Student project overview

This trialled student project uses a 4th-year Undergraduate Industrial Design project as the lens to examine an approach to data use for new product development. The project focus considered "How can electronic integration read terrain and provide a reliable geometry adjustment system for mountain bikes?" This project question was deduced after the initial research and market gap identification around mountain bike geometry affecting stability and performance. The sport of mountain biking is very popular, with several sub-disciplines coming under the mountain biking category, each with particular preferences for specific frame geometries. Bike dynamics and geometry are quite complex. [5] Recent work has been done to explain stability and bicycle control, computational models have been developed to support dynamics assessment. However "The relationship between design and behaviour is shown to be heavily speed-dependent and complex” [12]. Vehicle dynamics define non-subjective aspects such as stability and dynamics, how a bicycle feels to the rider is "subjective opinion"[8]. There are some 'knowns' such as; changing the head angle increases or decreases stability and responsiveness at different speeds depending on the angle, a short chain stay provides a more dynamic ride in the back end of the bicycle. These aspects are explained in the literature along with a number of other relationships. With a bicycle, even small changes in the basic variables such as bicycle geometry, rider height, weight, skill, and varied course routes that include slow, fast, inclines and declines all influence the feeling of stability. Therefore, there are many variables making mountain bicycle performance challenging to evaluate. The student identified that a dynamic, responsive system to adjust the geometry to increase bicycle handling characteristics based on speed and incline would make sense to develop. The system would adjust on the fly to suit stability vs power geometry depending on conditions and rider preference needs. A product design approach rather than an engineering approach is needed to produce a product concept within the timeframe of an undergraduate project due to the above discussed variables. However, if the engineering data collection methods were used more loosely, valuable data could be collected to guide the design project.

2.4 Data collection and data processing for visualisation and real-world workflow

Keeping student projects simple enough to execute, and at the same time with enough research training, it was decided that collecting quantitative data that verified bicycle geometry stability through MOU sensors rather than opinion would be the approach. MOU sensors come in several forms, from high-calibrated research equipment to inexpensive Arduino board MOU add-ons. Capturing quality data accurately required at least four considerations; repeatability, accuracy of test equipment, test rig design, data processing and visualisation. Immediately there is a test complexity that is a yearlong project in itself. This was a design project, not an engineering project. There was no test lab and no high-end test equipment available. Research equipment commonly comes with proprietary software to aid in data capture and visualisation; accessing this was not an option for this project. The data collection approach was formulated through how the data could be visualised using software, visualisations being the preferred language of designers, so this was the main criteria for selection. Python, R and MatLab are commonly used in teaching environments to visualise data, Matlab more specifically is used in engineering and data analysis[10]. Matlab, "Rather than relying on some foundational knowledge of coding or computer science policies, MatLab instead allows users to get a more intuitive read on their data"[10]. This coupled with; accessible proprietary software training, integrated smartphone accelerometer and GPS data capture software and Simulink, Matlabs integrated ecosystem of products lent the selection towards Matlab. Visualising data is one thing, utilising this for machine control or machine learning is another. Simulink would support an experimental workflow for this development in a real-world application, therefore supporting the appropriateness of MatLab is a tool for this application. As discussed, design projects and design problem-solving methods vary, there is no discipline-specific data practise paradigm for product design or industrial design, therefore, due to product development practice links with engineering disciplines, MatLab was trialled. It was also decided that the Matlab ecosystem could support an array of design projects from big data sets, often used to identify issues relating to 'wicked' problems, through to engineering data analysis and machine control.

2.5 Data capture approach

What does mountain bike stability look like in data? This was the first student project question needing to be answered. Question two was to confirm if this was measurable. It was decided that stability for the project would be assessed through an absolute frame and handlebar direction field testing experiment and if a higher variance was found, this indicated less stability. There are other ways of assessing stability, however these were discounted to reduce the number of variations in the experiment.

2.6 Student project outline

Developing a faultless experiment in the context of a design project in an undergraduate product design degree in all but the most straightforward projects would be unrealistic as discussed above. However, in setting methods and parameters for this experiment, reducing variables and increasing repeatability with resources accessible was the goal. Quantifiable in-the-field testing results for stability are not freely or identifiably available for mountain bikes in the literature; this may be due to the mountain biking industry's infancy, or a desire to keep proprietary knowledge secret. Either way, data was not available and needed to be captured by means accessible by the student. A broad overview of the data capture experiment will be covered below for context and is not an exhaustible discussion of the experiment.

<u>Aim</u> - To run an experiment to quantifiably classify a difference between two mountain bike geometries. Expert sponsored team riders identify a difference between lively and slack/stable geometry mountain bike setups in the industry, however these are based on professional opinion, not quantifiable data. The project aimed to collect quantifiable variance data.

<u>Hypothesis</u> - That it is possible to identify variance and classify variance between the absolute frame and handlebar direction of two mountain bike geometries in a real-world environment by logging azimuth, pitch, roll and MALMS to identify lively and slack geometry.

<u>Methods</u>

Equipment - To assess stability, a rig was required, this included; two smartphones running Matlab Mobile, the MathWorks data logging app, a mountain bike with a two setting manual geometry adjustment system, and stable phone mountings to secure the two smartphones.

Environment - A 140-meter section of test track was identified for the 'in the field' data capture. This included cross country inclines, declines and corners, hypothetically some sections favouring

‘slack/stable’ geometry and other sections favouring ‘lively’ geometry.
Process – To reduce variability in time to complete the course, trail runs were carried out until there was consistency in rider performance. Next, data logging test runs were completed, the most consistent time-based logs were used to compare the two different mountain bike geometries for stability comparison. Using smartphones running Matlab mobile; azimuth, pitch, roll, MALMS and GPS coordinates were logged along the 140-meter track. This data was logged, then graphed using Matlab and viewed as overlapping events, the most consistent time events were used. In the graphs a variation could be identified. GPS coordinates of the event were mapped alongside the graphs helping visualise event occurrences in the graphs.

Results

A classifiable difference between the mountain bike geometries was extrapolated from the data, supporting the hypothesis that variance between the absolute frame and handlebar direction is an identifier of stability. This result is consistent with professional rider opinion. Interestingly, the student test rider identified points where stability was felt however this did not necessarily reflect in the data. Another data point may be required to capture the whole rider experience completely. However, the already captured data is arguably all that is needed for the machine learning system design to operate effectively.

2.7 ‘In the field’ experiments

'In the field' experiments are challenging to set up and are open to a wide variety of variabilities and interpretations. This may prove too challenging in some instances for scientific professions to engage in, the degree of difficulty for replicability of data quality in experimentation may reduce their commitment to ‘in the field experiments’. Designers are more comfortable with making mistakes or finding variance in results. This may be an advantage for the design professions in new product development industries and, conversely, less successful for incremental innovation where the scientific process of variable reduction is possible. Designers use intuition more frequently to move projects forward quickly. This may also be true for the intuition of the data capture and the interpretation process. Some supporting data, not definitive data, maybe is all a designer needs to move a project forward. The success of new product development in consumer item categories does not necessarily rely on data, but on intuition, using a variety of inputs, including some data, may improve outcomes. For example, we have seen many heavily data-driven new products fail in the marketplace; think of Google Glass as an example. One way forward may be to encompass using data, but not relying on data. A designer data intuition product development process may serve as an appropriate method in new product development.

3 WHY IS A DISCIPLINE-SPECIFIC DATA PRACTISE PARADIGM IMPORTANT?

Understanding the way quantifiable data is; captured, cleaned for use, what patterns are discoverable, all provides a valuable framework with which to work. Designers can use data as hard and fast facts, inspiration, or a building block for intuition. Data can also be used as a design medium to augment or adapt experience through machine learning adaptations using Matlab Simulink. Identifying what a version of ‘stability’ looked like was a starting point for identifying and accessing what data is needed for machine control solutions. Some data handling programs integrate with machine control software, so it is possible to realistically develop and experiment with machine learning to solve design problems. Simulink, the Matlab add-on, is a primary example of this integrated system. Further to this, identifying 'stability' in the data, inspired a discussion around; if we can identify stability through data, and we can identify which geometry is better for the different conditions based on data, then we can create not only a device that changes according to the physical condition, but it is possible to consider an interface that adapts over time using machine learning. We can then also discuss interfaces that communicate more than basic condition settings of setting 1 or 2. Discussions around what the product should look like, what the UI is for this type of product. Is it a UX interface, or a TUI interface, is it a combination of both? New product development is currently grappling with these issues, especially in the health and fitness realm. Collecting data, looking at what data might infer, then thinking about how to integrate this data usefully into a product is a valuable discussion to have with undergraduate students. Therefore, we need to develop a discipline specific data practise paradigm for product design to prepare our undergraduate students better.

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REORIENTING DESIGN THINKING THROUGH SYSTEMS THINKING

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ABSTRACT

In this paper, we discuss how systems thinking can serve as an entry point to a re-oriented design thinking process model where equal value is attached to nature, the non-human and the humane. Design thinking matured at a time (mid 90s - 00s) when climate and environment did not receive the same attention as in recent years. We believe that design thinking still has its justification as a process tool. However, we want to discuss if design thinking as a process tool can be strengthened if we supplement the process with a consistent focus on ecosystems and systems thinking. In this paper, we specifically address and discuss the role of systems thinking and systems mapping as perspectives to reorient the design thinking process in the 2020s where natural recovery and green transition should have the highest priority as a result of the general state of the planet. In two projects, a module course for innovation and entrepreneurship and an international co-curricular project on systems mapping, we have employed systems thinking at different phases in the design thinking process. In this paper, we evaluate in which ways and to what extent systems thinking has contributed to the learning process. We exemplify and argue how students have obtained a deeper understanding of the complexity of 'wicked problems' and the mechanisms causing them. In conclusion, we point to a potential for reorienting the design thinking process by combining it with systems thinking and approaching it as a continuous movement between ontological and operational perspectives.

Keywords: Design thinking process, systems thinking, GPA Map the System, Design for Change

1 DESIGN EDUCATION FOR SUSTAINABLE DEVELOPMENT

In the OECD's 2030 Future of Education and Skills report, design is the most frequent word used to describe examples of new, emerging jobs and future skills for a complex and changing world [1]. Moreover, the World Economic Forum's Future of Jobs report particularly mentions and describes design as one of the most significant change-making practices [2: 36]. The distinctive approach to problem solving through a human-centred and visually-oriented methodology employed by designers—also central to design thinking—strives to develop new opportunities instead of selecting from already existing alternatives [3]. When designers engage in wicked problems [4, 5], they often develop new methods [6, 7]. This requires an awareness of the educators designing the curricula about which type of design they are aiming at but also on what premises - on what ontological basis they work.

In 1992, Buchanan suggested a design typology consisting of four orders of design [5]. He described the first order of design as communication with symbols and images and the second order as industrial design, engineering or architecture focusing on physical artefacts. The third order is described as interaction design in services and is about how people relate to other people. Finally, Buchanan pointed at the fourth order of design as the design of the environments and complex systems. Buchanan emphasized that *"[s]igns, things, and actions are organized in complex environments by a unifying idea or thought"*, that is, the three first orders of design exist within the fourth order (5: 10).

Aiming to direct students towards the third and fourth orders of design points towards including systems thinking as it allows us to reorient our thinking from being entity-focused (a product, a local problem, a specific person) to include multiple entities (products and services, multiple problems, multiple stakeholders), their interrelations, the dynamics of the system, and very importantly the different scales of the system [9]. Other researchers have linked design thinking and systems thinking within the field of design and sustainability [10, 11], but also earlier design research seems to point to systems thinking [12]. Buchanan explains it in this way:

> *"Systems thinking reveals the complexity, interrelationships, and many of the interdependencies that exist in our surroundings. But it does not lead to action except through the agency of the discipline of design, an art of action. Design is more than the set of methods and techniques to which it is often reduced in the approaches of system thinking. Design and the thinking upon which it depends is a cultural and humanistic art, a discipline of transforming surroundings into environments for human experience" [8:100].*

Our intention with combining systems thinking with design thinking is to provide students with an understanding of the status quo and the dynamics and scales of a specific system, thus providing them with tools of action through design thinking process models. Systems thinking contributes to identify system interrelations where changes can be put in action. That is, it can create an understanding of beneficial points of intervention. Meadows promotes these as leverage points where the scale of the interrelation and the leverage point together define the scale of the potential change an action brings [13].

2 DESIGN THINKING AS A PROCESS TOOL

In the last decades, design thinking has been widely used as a process model in educational as well as in business contexts, especially. This was heavily influenced by the work of Tim Brown and IDEO at the beginning of the 2000s [14]. This seems to have moved the focus of design thinking from being a process to solve 'wicked problems' such as environmental issues and inequality [4, 5] to being a process predominantly applied to ensure continuous growth in a conventional linear growth paradigm. In that way, it can be argued that design thinking has moved from a focus on design in the fourth order (environmental designs and system interventions), and third order (interaction design) to a predominant focus on design in the first and second order (products and services). Thus, we contend that time has come to initiate a transformation from user-centred to beyond-human centred design. This paper presents elements of our work with reorienting design thinking through systems thinking and mapping for pluralistic futures.

Design thinking matured at a time (mid 90s - 00s) when climate and environment did not receive the same attention as in recent years. We believe that design thinking still has its justification as a process tool. In this paper, we specifically address and discuss the role of systems thinking and systems mapping as perspectives to reorient the design thinking process in the current context where recovery of (natural) resources and green transition should be given highest priority. Design thinking emphasizes research as the first step of defining a relevant problem. This can typically be in the form of 'empathizing' (Ideo, Stanford), 'discovering' (Double Diamond, British Design Council) or 'finding' (5F, VIA University College). Common for these models is that they are based on an Anthropocene understanding with a human-centred focus. In this paper, we discuss how systems thinking can serve as an entry point to a reoriented design thinking process model where nature and the non-human are given equal consideration as humans.

3 RESEARCH METHODOLOGY

In this study, we base our research on two educational projects from HE in design. We have employed systems thinking at different phases in the design thinking process. 'Design for Change' (DfC) is a three-week course module with 48 'Entrepreneurship and Innovation' BA students on their 5th semester. The students have applied systems thinking to their projects throughout the whole process with an intensified focus on the solution. The purpose of the Design for Change course module is to qualify students to take part in and use their maturing professional knowledge to work with complex, sustainable, circular and socially oriented design solutions.

'GPA Map the System' (MtS) is a 10-week long learning experience offered in collaboration between Canadian Humber College, Otago Polytechnic and VIA University College for students to build key competencies for sustainable development through activities focused on systems thinking and mapping [15]. The students have used systems thinking specifically in the initial phases to find and re-frame a problem through systems mapping.

It applies to both educational projects that the students are familiar with and have worked with one or more versions of design thinking as a process tool. The students have worked in groups of 4-5 people, and we have selected representatives from different groups for interviews. We use the interviews as a foundation for our discussions. We have worked qualitatively with an interview guide with open questions focusing on the students' experiences with systems thinking and mapping. The subsequent analysis is conducted according to the following four themes: 1) reflections on the work with systems thinking, 2) new perspectives in working with innovation projects, 3) the relationship between systems thinking and design thinking, 4) transfer of new knowledge about systems thinking and mapping for subsequent projects.

Our main interest in this paper is the students' reflections on design thinking combined with systems thinking. Therefore, and due to limited space, we do not bring examples from teaching but focus solely on the interviews. The interviews have been conducted physically or online with the participation of two researchers and one student. Each interview had a duration of approximately half an hour. Each interview has been recorded and transcribed and supplementary notes have been taken.

4 INTERVIEWS & ANALYSES

The thematic analysis reveals that the students have obtained very different types of insights during their introduction to systems thinking, indicating that there are different levels of abstraction. Though insights gleaned from a few broad interviews do not provide strong evidence, they are valuable from a didactic perspective as input for further investigations into reorienting our didactic approach to design thinking Some students reveal how systems thinking has provided them with a set of tools that enable them to operationalize systems thinking (e.g., through systems mapping) and use it communicatively to ensure that team members have a common understanding of the problem. Others have gained an increased ability to identify and engage in the interplay between elements that – in combination – create the complexity of wicked problems.

Overall, it seems that all students have gained an increased awareness of the complexity that surrounds them and that problems are multi-layered. However, there appears to be considerable differences in the understanding of the interrelation between complexity, wicked problems and systems thinking. Some students elaborate on their experiences with concrete examples of systems thinking methods and tools they have used, specifically emphasizing systems mapping. However, they appear less familiar with the ontological perspectives of systems thinking. Other students explain how obtaining knowledge about systems thinking has contributed to constructing better research questions, thus enabling them to address elements that lie beneath the surface.

The following key insights from the interviews are divided into the four themes. The two types of learning outcomes - operational and ontological – are illustrated for each theme.

4.1 Reflections on the work with systems thinking

Through their experiences with applying systems thinking in the GPA Map the System project as well as in subsequent courses, a student had developed an understanding and appreciation of systems and the depth and complexity that they entail:

> *"Systems are all around us, we just don't see it… we don't realise it… and then when you really dive in for it, you find out that a lot of areas are not transparent… There are a lot of why's behind and sometimes you can [desk] research for the why, but sometimes you need to get the primary research as well. You need to talk to people to understand and even people who work within the system, let's just say the waste management people, they also couldn't answer that question because they're in the loop. They can't think about why because this is just what they do daily" (Student C, MtS).*

In trying to get to the 'why' of something, the student has come to the realization that while primary research with embedded stakeholders of a system is often required, they (the stakeholders) might not be able to see the system from the outside. They do not have or cannot take the perspective that systems thinking offers.

The same student offers an operational perspective as well that taps into an ontological learning outcome.

> *"I think we need to find a way to visualize or let's say translate what you thought and the whole system. It helped me a lot… To me when you have the tool, it's very simple to expand to people to see the big picture because when I just see it, it could be something messy and people maybe couldn't follow. But with all the tools, it helped a lot" (Student C, MtS).*

As the examples by this particular student show, the systems mapping tools have empowered the students to communicate systems thinking perspectives and invite others (e.g., fellow teammates or stakeholders involved) into the arena of systems thinking where new understanding and knowledge can arise. Even without drawing them, the maps become conceptual frameworks for thinking in and about systems.

4.2 New perspectives on working with innovation projects

In hindsight, some students now see that prior to the course Design for Change, their projects had simplistic understandings of the problems they were working on, leading them to question the rationale behind their solutions or proposals. One student frame the learning outcome as

> *"Systems thinking is about going back to the roots, not leaving anything out, not treating the symptoms but addressing the underlying causes" (Student A, DfC).*

While some students might attack wicked problems head-on, albeit sometimes with a simplistic understanding of the problem, others might be hesitant and feel overwhelmed by the sheer complexity of the problem. As one student puts it:

> *"It definitely gave me a tool to try to map the complexity […], there are some wicked problems and it's just confusing and hard to think about. And there's… Yeah, not much I can do. But with systems thinking, ideally it would be a tool to combat wicked problems" (Student E, DfC).*

Here, systems thinking operationalized through systems mapping seems to help some students overcome the feeling of inefficacy by giving them an overview of potential points of intervention.

4.3 The relationship between systems thinking and design thinking

Students from GPA Map the System as well as Design for Change emphasize that knowledge about systems mapping and systems thinking enables them to understand the status quo at the beginning of a design thinking process. Here it is expressed by a student from GPA Map the System:

> *"… Because we use the website Kumu.io. Because you have a lot of templates you could use different visualizations if you want. So first of all, we try to create categories for our project. We were working on food waste within the north of Europe, so Scandinavia. And so, first of all, it was to narrow it as much as possible because it would have been impossible to do it in the world. And so, at the beginning, each of us could present ideas and try to make maps, and then we would meet to try to see if we all agree with everyone's idea. And then we all met once. We could scrap out what was not working, try to make connections and always question why and why do we think it's connected?" (Student D, MtS).*

The student describes how systems thinking enables the group to work with and qualify the problem framing – a design thinking tool – supported (and challenged) by systems thinking.

4.4 Transfer of new knowledge about systems thinking and mapping for subsequent projects

Nearly all students expressed those systems thinking had contributed to understanding the complexity and how everything is connected to working with 'real-life' wicked problems. A student from GPA Map the System expresses how systems mapping and the communication platform the group used was an eye opener to the extent that s/he has used it afterwards for the individual BA project:

> *"But the mapping tool was really interesting, and I actually used this website again in my bachelor thesis and in my other projects afterwards because I just used it for myself sometimes, for example when I was brainstorming. When I was researching a topic, I would try to… if I had different topics in mind or different areas of research, I could put it in the center and try to see what would come up. I also used it in connection with engineering to list properties of materials and to test those properties" (Student D, MtS).*

Contrary, a student from Design for Change expressed how the mental model behind systems thinking was the most important learning take-away:

> *"I definitely think it can help me in solving problems. I mean I use it as a kind of a mental model. I don't use the different tools within systems thinking … Just using the mental model that thinks in terms of systems, thinks in terms of patterns, that is something helpful that I definitely took with me from the course" (Student E, DfC).*

This statement particularly emphasized that instead of introducing the concept of systems thinking and wicked problems at a high level of complexity, we should start with a more bottom-up approach and exemplify with less complex problems as a framework.

The analysis focusing on the four themes points to two perspectives of knowledge and doing. In the next section, we suggest discussing this as an ontological versus an operational perspective.

5 DISCUSSIONS

Unintentionally, the students use both an ontological perspective (their knowledge perspective) and an operational perspective (their "doing" perspective). Some students move effortlessly between the two perspectives. For these students, the ontological and operational perspectives are equally important, and they appear to move continuously between them in interconnected and expanding curves as their levels of knowledge and dimensions of abstraction expand (Figure 1).

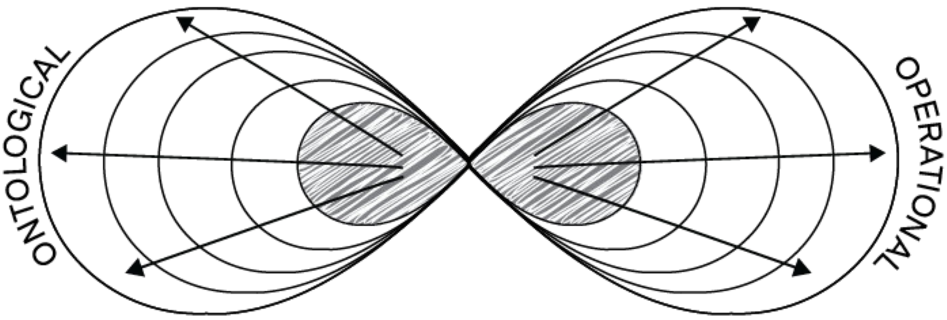

Figure 1. The figure shows the connection between ontological and operational perspectives and how the level of knowledge and dimensions of abstraction can expand.

The ontological and the operational perspective are thus approached as both/and rather than either/or. These students use systems thinking constructively as an approach to understanding 'wicked problems' by breaking them down into smaller entities that help reduce complexity. Other students are predominantly engaged in the operational perspectives and the use of the related tools.

Merging systems thinking with design thinking is not easy and requires fundamental awareness in the process – profound reflections on the ethics, values and principles of the systems in which the designer works. This calls for a revision of the ontologies on the basis of which we perceive the world. Buchanan explains:

> *"The neglect of principles sometimes leads to the complicity of designers and system thinkers in the failures of the large platforms—technological or social— that affect our lives. Overcoming this neglect is a challenge for which the design and systems communities may not be well prepared, since there is often too little discussion of the nature and influence of principles in making and living our lives. Yet, it is the kind of challenge to which the disciplines and our diverse philosophical beliefs can turn if we have the will and the restless imagination that characterizes creative design" [8: 102].*

As discussed in the analysis of the interviews, the introduction of systems thinking to design thinking has achieved some of the intended results; some students have obtained a deeper understanding of the complexity in 'wicked' problems and the mechanisms causing them. Thus, they pay more attention to and spend more time exploring and understanding the systems creating the problems. Though not conclusively, the students participating in GPA Map the System appeared to have gained a deeper understanding of systems thinking both as a concept to understand different ontologies *and* to employ different tools to map and communicate systems. Moreover, these students appeared more capable of reflecting on how they transferred their obtained systems thinking knowledge to subsequent projects and in general included it in their work approaches.

6 CONCLUSIONS

Since several students apparently perceived systems thinking as merely a set of tools to organize or map elements constituting their normal research process, e.g., mapping of stakeholders, research areas and data sets, it seems relevant to evaluate and scrutinize the didactic approach to systems thinking as integrated in design thinking. The big difference between the didactic approaches relates to the introduction of systems thinking limited to the frontend of the design thinking process (GPA Map the System) against introducing systems thinking throughout the whole design thinking process with high focus on the final idea and solution of the defined problem (Design for Change). While there is a potential risk of a continuous communication of design thinking as a linear process model, there might be potential in reorienting the process and use systems thinking in the initial phases where the problem is identified and framed. Generally, these two phases are seen as first a divergent phase (research and identification of problems) followed by a convergent phase (framing the problem and creating the research question). With the experiences from the two educational projects discussed in this paper, we see a potential in providing the students with improved tools to identify places to intervene in a system. This will enable them to approach the system and thus the identified wicked problem, continually moving between ontological and operational perspectives.

In conclusion, the insight from this study points to a potential in reorienting the design thinking process by combining it with systems thinking.

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BRIDGING THE EMPATHY GAP: IMPROVING DESIGN EMPATHY ACROSS CULTURAL BARRIERS

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ABSTRACT

Human-Centred Design (HCD) has become a key component of design teaching over the last thirty years. Central to HCD is the concept of design empathy, and many techniques and tools have been developed in order to encourage and help designers to gain a greater understanding of the specific difficulties, desires and behaviours of their target users.

Bournemouth University (BU) Design and Engineering students have long been encouraged to make use of HCD techniques as part of their creative design process. However, their work alongside the Royal National Lifeboat Institute (RNLI) in developing products aimed at Low-to-Middle Income Countries (LMIC's) has highlighted shortfalls in these techniques, which are often more suited to designing for the elderly or disabled rather than users from an unfamiliar cultural, social or economic background. Furthermore, an Empathy Quotient survey of level 6 Design and Engineering students at BU indicated that empathy levels were no higher than the national average despite years of exposure to HCD methods. After a collaborative project in Tanzania during which local partners were introduced to using HCD tools to encourage design empathy, the authors facilitated an ideation project using postgraduate Design and Engineering students from BU. This paper explores the issues in improving design communication and empathy across cultural barriers. Using data obtained from the UK students the authors investigate the perceived value of empathic tools, whether modern and emerging technologies could offer ways to bridge the cultural empathy gap, or whether in-country upskilling in design methods offers a more sustainable solution.

Keywords: Empathy, LMIC, empathic design, Human-Centred Design

1 THE EMPATHY GAP

In 2013, as part of his BBCTV documentary 'Don't Panic: The Truth About Population', the academic and statistician Hans Rosling conducted a survey into the general public's perception of global population, income, literacy and health. Typical multiple-choice questions included the following:

- What is the average life expectancy of the world's population?
- What is the global adult literacy rate?
- On average, men aged 25-34 have spent eight years at school. What is the average for women of the same age group?

The results were startling, revealing that in most cases British people performed worse than chimpanzees picking responses at random. Rosling deducted that the core issue was not simply ignorance:

"Doing worse than random means the problem isn't a simple lack of knowledge. The problem is preconceived ideas." [1]

Over the past few years at Bournemouth University (BU) a significant proportion of level 6 undergraduates on the BA/BSc/MDes Design and Engineering courses have undertaken major projects to create design solutions for problems in low-to-middle income countries (LMIC's). Often these have been in the form of live briefs with the Royal National Lifeboat Institute (RNLI), and solutions have included floatation aids, child playpens and a bicycle ambulance.

In order to create effective design solutions, the students must be able to empathise with the prospective users. Given the results of Rosling's survey, and the difficulties faced by the students in obtaining direct contact with the LMIC market, the authors suspected there was a shortfall in the students' ability to

empathise with non-UK users from an unfamiliar cultural, social or economic background. This paper investigates whether these suspicions were correct, and what can be done to address this issue.
At this point it may be useful to briefly define the context within which the authors will be discussing empathy. It will not be within the scope of this paper to define empathy per se. However, it is important to note that this paper will concern itself with cognitive empathy – that is, the ability to understand another person's perspective or mental state – rather than affective empathy (aka emotional empathy). These two components are distinct, with no interdependence, and utilise different parts of the brain [2].

2 MEASURING EMPATHY

A large number of methods have been developed in order to try to assess levels of empathy. McDonagh-Philp and Denton [3] developed the concept of the 'empathic horizon' to define a designer's capacity to "empathise beyond certain characteristics of his or her group". The Empathy Quotient (EQ) is a widely used paper-based tool designed by Simon Baron-Cohen and Sally Wheelwright at the Autism Research Centre at the University of Cambridge. The EQ comprises a questionnaire containing 60 items, to determine the 'empathic horizon' of the respondent [4].

2.1 EQ survey results

In 2019 the authors asked a group of level 6 Design and Engineering undergraduates from BU to complete the EQ questionnaire. Amongst a sample of 36 students only 19% of students achieved an EQ score which equated to 'above average'. Despite participating in academic units designed to encourage students to employ empathic methodology as part of their design process, the students performed no better than the national average in the EQ test. Literature commonly indicates that females tend to score higher on the Empathy Quotient and tend to have more cognitive empathy then males [5], and this was reflected in our survey with participants identifying as female achieving slightly higher EQ scores than males.

3 USING EMPATHIC DESIGN TOOLS IN AN LMIC CONTEXT

Defined by Battarbee et al. [6] as "leaving the design office and becoming immersed in the lives, environments, attitudes, experiences and dreams of the future users", empathic design has become a core element in design teaching, and a crucial part of the design process.
A range of tools and techniques have been developed over the years to enable empathic design, and these have been ordered into three basic approaches: looking at what people do; asking people to participate; and trying things for yourself [7]. Kouprie and Sleeswijk-Visser broke these three approaches down further into four steps: discovery; immersion; connection; and detachment (analysis) [8]. To empathise fully, a designer should engage in all twelve of these steps. In particular, direct contact is encouraged by proponents of empathic design. While this methodology is well suited to designing for groups with whom interaction is relatively easy, it can offer major problems in an LMIC context.
In the absence of direct contact, a number of 'communication techniques' have been proposed by HCD proponents, which involve the collection and analysis of user data by external researchers to be passed on to the designer. To improve the personal connection, it is advised that first-hand information direct from the users - such as diaries and self-taken photographs - is also collected [9]. However, these are time-consuming and costly solutions rarely available to students working on LMIC projects.

3.1 The international and intercultural divide

Differences in such characteristics as language, culture and skin colour can affect an individual's ability to empathise [10], and lack of interaction also has a significant effect on empathy between individuals [11]. However, direct contact in the context of international design does not necessarily result in a more empathetic approach, or successful designs. Dasan and Sheldrick's research relating to the Dyson School of Design Engineering's experience in international collaborative design projects highlight both the benefits and drawbacks of students from different cultures working together. In common with previous researchers, they found that such projects often promise much but deliver little [12]; that they often foster a negative 'Design Tourism' which focusses more heavily on the benefits to the visiting students than to the receiving individuals; and that there is a very real possibility of inflicting more harm than good on the local community. In general, the result was "ineffective and poorly executed projects" [13].
However, the application of HCD, Design Thinking and empathy tools in sustainable development has gained traction in recent years. These require the design team to utilise ethnographic principles to

understand emotions and behaviours at the very start of the design process, as illustrated, for example, in Stanford University's 'ethnography field guide' [14].
Development organisations such as UNICEF have recruited designers and leading funders in the global health space, such as USAID and the Bill & Melinda Gates Foundation, and they have created dedicated roles and funding streams to increase the application of design thinking within their portfolios. Some donors – such as the GCRF fund - are even requiring it as a precondition of funding.
Design for Health [15] reports that more than 35 projects have used design as an essential component of a global health program. Positive evidence of the effectiveness of this approach is emerging and is highlighted in Bazzano et al scoping review in the PLOS ONE journal [16].

4 EMPATHIES FOR TANZANIAN FISHERS

Over the past two years the RNLI have been working alongside Design Without Borders Uganda to address the very high drowning rate amongst the artisanal fishing community in Lake Victoria, Tanzania. [17]. Co-design has been central to this project and in order to assist with this, local project partners in Tanzania were introduced to using HCD tools to encourage design empathy. In tandem with this, the authors facilitated an ideation project to design a weather reporting system for the same community, for postgraduate Design and Engineering students from BU.
In order to assess the effectiveness of the HCD tools and methods used in this project, questionnaires were given to the participating students, and the responses were analysed.

4.1 BU student survey results

The students were asked to rate the usefulness of various HCD tools both before and after the ideation project (Figure 1), as well as their perceived level of design empathy towards the fishers. They were also asked if any other sources or forms of information would have helped them to gain more design empathy. In total 22 students responded to the first survey and 26 to the second survey.

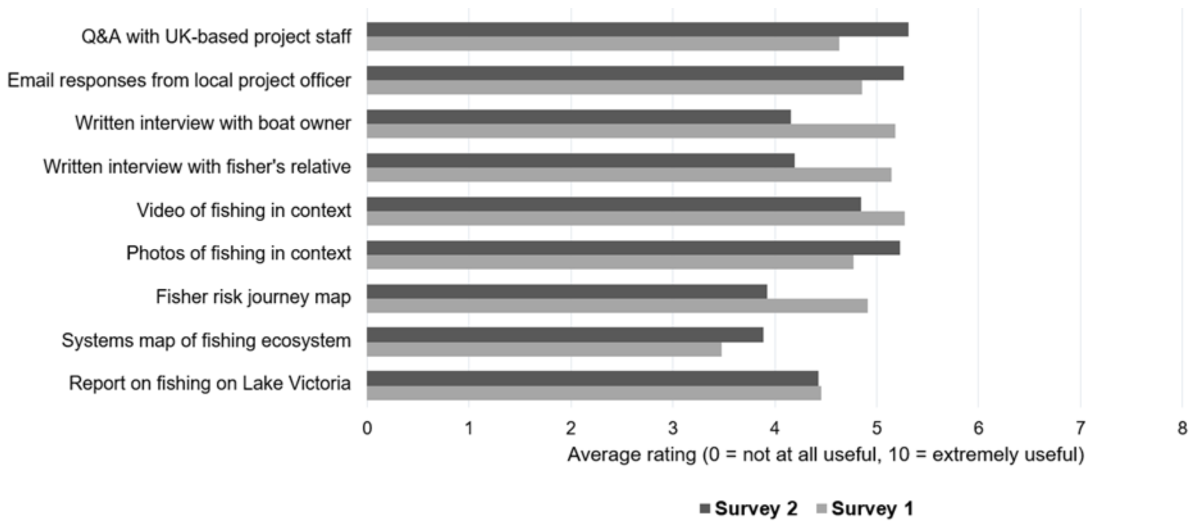

Figure 1.

Prior to the start of the project the students perceived that interviews with local boat owners and fisher's relatives would be more useful than contact with local project officers and UK-based project staff with experience of working with stakeholders in Tanzania, but by the end of the project this perception had been reversed. Despite this, several students suggested that further direct contact with local boat manufacturers, family members and the fishers themselves would have been useful.
Interestingly, while a video of artisanal fishing in context was seen as the most useful tool at the start of the project, the students actually found that photographs were a better way of gaining empathy. The fisher's risk journey map also proved considerably less useful than expected.
Overall, the students perceived a marked increase in their level of design empathy, with the average rating increasing from 6.1 to 7.6, with 85% of respondents giving a rating of 7 or more after the project compared to just 36% before.

5 TOOLS FOR THE FUTURE

One of the major barriers facing both students and professionals is access to relevant data. One BU graduate told the authors that, in his view, taking on a LMIC project could present a considerable handicap to students:

"I think the university expects a lot of students working on these types of briefs, in terms of obtaining first-hand information for hard-to-reach markets/users."

Advances in telecommunications over the past thirty years have obviously contributed greatly to improving access to information. However, the sheer quantity and variability of the data has not necessarily improved knowledge of – or empathy for – LMICs. The widespread recognition of the "echo chamber" effect of social media [18] appears to confirm that it has a role in confirming – rather than contradicting – the problematic "preconceived ideas" identified by Rosling as a barrier to empathy [1].

5.1 Improving access to reliable data

The availability of reliable data does of course depend largely on the nature of the project, but one common issue with LMIC projects is in gaining a realistic view of the user's way of life. One online resource that attempts to address this problem is Dollar Street.

Dollar Street was created by the independent Swedish foundation Gapminder, whose stated goal is to "fight devastating misconceptions about global development with a fact-based worldview everyone can understand" [19]. The Dollar Street website currently presents a detailed photographic record of over 260 homes in 50 countries around the world, representing a broad range of financial and cultural experiences. The key to Dollar Street's value to designers is in the mundane nature of the items photographed: from favourite shoes to toothbrushes, cooking utensils to toilets, it provides an honest and instantly accessible window into hundreds of lives across the world.

Dollar Street's photographic and video database is constantly expanding, and this type of knowledge-sharing offers huge potential for improving empathic design. Co-operation is key, as one BU graduate told the authors:

"It would be extremely valuable to students working on these briefs if the University and lecturers continued to build links with organisations working across the world. These links could be used to the students' advantage, as a means of helping them obtain first-hand information".

A particularly effective method of achieving this level of co-operation would be through a community of practice. Such a resource would provide a repository of pooled knowledge and resources that would expand over time, as well as creating a social and professional network of experts, students and practitioners. While communities of practice have been long established in fields such as agriculture and education, their adoption in design has been surprisingly slow. An effective LMIC design community of practice would be a hugely useful resource for tackling the international empathy gap.

5.2 Direct communication

Much of the problem in obtaining reliable information stems from the editorial and subjective nature of much of the content of the web. Information on LMICs is rarely received direct and unfiltered. Direct communication with potential users is therefore a key strategy in improving empathy. Of course, international telephony has existed for well over a century, but it is the use of email and apps such as Skype and WhatsApp that have truly changed the landscape for young designers by offering free international communication. Video calling in particular provides a hugely valuable aid to empathy, as it offers both parties a more immersive, informative window into another person's environment.

Since the advent of the Coronavirus epidemic, video platforms such as Zoom, Skype and Microsoft Teams have rapidly become mainstays of the educational landscape, and out of necessity many students have found them to be a hugely valuable tool in conducting research. The new-found access to, and familiarity with, these platforms could prove to be a major boost for empathy in international projects. More of an issue may be the restrictions imposed by ethical codes of practice on research, which may prevent many University students from directly contacting stakeholders in other countries.

An interesting development in the area of communications is the promise of 'holographic' technology. In 2017, US company Verizon and Korean Telecom trialled the world's first live international hologram call, and further similar 'early stage' trials have taken place in many countries. While these trials have required the use of virtual reality (VR) headsets, Richard Foggie of the Knowledge Transfer Network

believes that the 5G network has made ‘true’ holograms achievable in the near future: “within five years I think we'll see AR/VR [augmented reality/virtual reality] just sprout out of the phone." [20]
Using different technology, Imperial College in London has experimented with ‘holographic’ lecturers, beamed into lecture theatres via glass screens and careful lighting. While this technique does not create true holograms, Imperial’s Dr David Lefevre believes the effect provides “a greater sense of presence” than standard video conferencing: "So long as the technology works the way we believe it will, I can see this becoming fairly mainstream." [21]

5.3 Virtual reality environments

The use of VR is not limited to creating ‘holographic’ conversations. Organisations such as Oxfam and Greenpeace have made use of the technology to provide an immersive experience to potential donors as a fundraising tool, giving users the chance to explore the Amazonian rainforest or war-torn Iraq [22][23]. The corresponding reported increase in donations may appear to suggest that VR increases empathy, but the research suggests that the truth is a little more complex. The VR lab at Stanford University has been investigating the link between VR and empathy for 15 years, and their results conclude that the most important element in the VR experience for promoting empathy is physical movement [24].
The RNLI - working alongside BU, University of the West of England, University of Southampton and the Centre for Injury Prevention and Research in Bangladesh – is currently engaged in a four-year project which plans to make use of VR technology in this way. By recreating existing village environments in virtual space and allowing UK-based researchers and designers to move around them from the perspective of both children and adults, the project aims to improve empathy in devising solutions to the very high drowning rates of young children in Bangladesh.

6 A FUTURE SHIFT IN DESIGN EMPATHY?

It can be argued that empathy is an essential skill for the designer. Empathy tools are seen as an integral part of the design process, that can be used to create useful insights about the user and inform optimal form and function. But what if the end user becomes the designer instead?
On early evidence, the RNLI’s attempts to introduce local project partners in Tanzania to HCD methods to address drowning rates on Lake Victoria have drawn a favourable response from participants. Similarly, Design Without Borders has also implemented this approach in Uganda by upskilling South Sudanese refugees and local partners in design methods to create their own change [25]. This approach negates the need for an empathy driven “design for” approach. ‘Participatory Action Research’ (PAR) takes a similar but distinctive approach in that it actively educates the user to conduct their own research, reflection and change [26], again alleviating the empathy gap issues described earlier in this paper.
The authors are currently engaged in the forementioned four-year project to address the drowning rates of young children in Bangladesh. This project is also planning to upskill a local team in HCD methods and engage the local communities in the design process. Co-design will be central, and it is hoped that more insight on the validity of in-country HCD upskilling for sustainable co-creation will result.
Approaches such as this may see a shift away from tools that enhance the empathy of the distanced designer and towards empathy being naturally embedded locally as part of the co-creation process.

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INITIAL FINDINGS FROM A NETWORK FOR SUSTAINABLE EXPERIENCE DESIGN EDUCATION

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ABSTRACT
Toward the common goal of sustainable consumption experiences, effective and efficient education methods and expertise can vary a lot in Finland and in Asia reflecting relevant characteristics. The goal of the Finland-Asia Network for Sustainable Experience Design Education (SEDE-FAN) project is to build the network of higher education institutes in Finland and in Asia so that successful efforts in Sustainable Experience Design Education in Finland and in Asia can be shared. Also, learnings acquired in not-so-successful trials in such educational endeavours can also be communicated. In this way, the knowledge and principles underpinning such educational methods and expertise can be collected, stored, exchanged, retrieved, reused and enhanced through the project. This paper reports the findings of the first-year efforts in the project where two institutions in Finland and one in Korea have conducted sustainable experience design education efforts. Particular focus is placed on how different education contexts are related with respective sustainable experience design education efforts. In that sense, it will be useful to design educators who would like to introduce sustainability issues in their design education.

Keywords: Sustainable experiences, experience design, design education, international network

1 INTRODUCTION
As experiences are created by all individual consumers and users under various contexts, the nature how sustainable consumption experiences are made reflects the characteristics of the actors and their cultures and living contexts. While the goals of sustainable experiences design education can be common, effective and efficient education methods and expertise can vary in many different regions and contexts. With the goal to build the network of higher education institutes in Finland and in various countries in Asia in order to share successful efforts in sustainable experience design education in Finland and in various countries in Asia, the Finland-Asia Network for Sustainable Experience Design Education (SEDE-FAN) project has been launched. In this way, the knowledge and principles underpinning such educational methods and expertise can be collected, stored, exchanged, retrieved, reused and enhanced through the network. The critical aspect of this project is the diversity of Asian partners and Finnish collaborators. The Asia network is to be composed of institutions in Korea, Singapore, China, and some South Asia countries. Kyung Hee University, Korea, and Nanyang Technological University, Singapore, have participated in this project since 2022.

Participating higher institutions offer diverse courses at undergraduate and graduate levels where the sustainable consumption and experience issues are educated in the form of design projects. Such design project-based learning efforts typically employ problem-based learning approaches through team-based projects. While the specific courses may have diverse detailed contexts of education, these courses share the underlying method of design thinking in that human-centred problem-solving method and mindset are transferred to students in possibility-focused and hypothesis-driven manner. For Finnish partners, not only regional characteristic and disciplinary diversities will be considered while all these institutions share the core “experience design” theme. University of Turku is the leading institution of SEDE-FAN project. University of Oulu has joined the network in 2022.

The issue of sustainability has been actively integrated into design and design education. Some efforts address sustainability as a part in design education, while others use design as a way for sustainability education [1]. The evolution of design for sustainability methods shows gradual transitions from a product innovation level to a product-service system [2] innovation level, and to a socio-technical system innovation level [3]. A higher emphasis has been placed on consumer activities and behavior

first, then this has evolved to encompass new services, educating and facilitating desirable consumption behaviours [4].
In the following sections, three sustainable experience design courses taught at University of Turku, University of Oulu and Kyung Hee University are briefly described with the overview, the course structure, special educational characteristics and their respective findings. Then comparisons of those characteristics are made for the three courses. Discussions on findings with those three courses in comparative and in collective manners are addressed together with some plan to support the courses in collective and in respective manners. Note that the goal of this paper is to understand how different some efforts for sustainable experience design education are and how these different efforts in the network can learn mutually from one another.

2 DESIGN THINKING COURSE

2.1 Overview

Learning of design thinking, as a problem-solving method and a mindset, which are applicable not only in design problems but also in business innovation is the primary goal of the introductory Design Thinking course of University of Turku. A conceptual design project on new services for a product has been conducted as the first team-based project in the design thinking course. The intent of this course is to equip students with design thinking problem solving method and mindset through various design projects. Particularly, service design thinking, which is design thinking in the context of service-dominant logic and experience economy, is primarily addressed. Whether service design is viewed as designing services or design for service, human activities and experiences are at the core of designing in this course.

2.2 Course structure

The design thinking course is an introductory course for master degree students. The core course activity includes several team-based or individual projects addressing design thinking and human understanding topics. The project spanned over 5 weeks where two-hour session on lecture and discussion is followed by two-hour session of design projects and critiquing on the same day. Students were grouped into three teams so that diversities of all three teams are supported [5]. The teams were asked to choose a product for which new service concepts are to be designed. The students were exposed to design thinking methodologies and after going through design thinking phases of *empathize*, *define*, and *ideate*, the teams brought about new service concepts for their respective products. Each team's presentation was followed up by instructor's critiquing. Note that the students became familiar with the underlying design thinking competency learning through individual exercises. The students conducted their second design thinking project with broader design issues for another 6 weeks before the course is closed.

2.3 Education characteristics

The course was designed in a way to enable the students to carry out their design activities in a structured way. The teams went through the empathize phase of their service design thinking process. For the define phase, the teams were introduced about user journey map, and they constructed journey maps with pain points and delight points identified. The student teams iterate a little with more empathy activities as well as define and some initial ideate activities. Then they were asked to build as-is service blueprints as key define phase design activities. After discussions with teams about their as-is service blueprints, the instructor introduced a case of product-service system design which contains some sustainability issue and explained the key *imagining* method for new services using the Context-Based Activity Modeling (CBAM) method [6]. Then student teams conducted their design activities of the ideate phase with some iterations including define and empathize phases. With their presentations of initial service design concepts, critiquing has been done with instructions to reflect on their services further so that improvements on their service design solutions can be made. The student teams conducted their ideate activities further with some iterations involving the empathize and the define phase activities. The final presentations of the teams' final service design proposals were done with critiquing comments by the instructor.
All three teams properly conducted design thinking projects with reasonable new service concepts proposed while their treatments of sustainability issues are widely varied. The E3 value modeling method [6] provided a structured mechanism to address ecological values in a balance manner with economic and experience values. Thus, all three teams smoothly addressed ecological values. As the

example case addressed reuse service issue, sustainability issue was gently introduced. The ways the teams reflected this issue in their respective project varied a lot among the three teams. This is at the level where sustainability is addressed in a minor manner as the primary learning goal is to learn design thinking.

2.4 Findings

Using the CBAM representation scheme of activities, detailed activity information can be systematically represented for *experience*, *design* and *education* activities. It is expected that those higher education institutions participating in the SEDE-FAN project have now a guide in how to report and represent their sustainable experience design education efforts using the framework [6]. While project-based design is a desirable way for learning design, some additional concerns can be combined so that specific learning activities are intertwined with design activities. By embedding certain learning activities together with project-based design tasks, smoother learning of certain design methods could be enabled. It would be desirable if the framework would include some reflection tools so that design learning stakeholders like students and instructors can represent and reflect their respective design and education activities. Design student experiences should also be evaluated as in Önal and Sener-Pedgley [7].

3 DIGITAL FABRICATION COURSE

3.1 Overview

Digital fabrication environment has the ability to influence the way design is taught and practiced. Thus, digital fabrication in the context of design education impacts both the processes and outcomes. Digital fabrication laboratory has a collaborative platform for students where they can meet and share innovative ideas. The main objective of the Digital Fabrication course at University of Oulu is to develop design skills and knowledge using digital manufacturing process while promoting sustainability, in a digital fabrication environment [8]. The earlier framework [9] for sustainable design and prototyping using digital fabrication has been refined and some sub-sustainability indicators as well as educational intervention to enhance sustainability practices has been identified in the course as conducted as a part of the network [8].

3.2 Course structure

In the beginning of the course, the instructors taught design and prototype development methodologies over the span of six weeks. During this period, significant components of the framework such as design awareness and environmental responsibility were discussed. The objective was to provide and enhance theoretical and practical knowledge of digital manufacturing process. In the second phase, student brought about their theoretical knowledge into practice through design prototyping. The instructors provided feedback on the design prototypes as well as substitute solutions while deriving students' attention towards sustainability. For example, utilization and reusing of electrical and mechanical components were handled. Students were assigned the task to design a 3D interactive prototype and design mechanical components for the prototype following by group discussion among the team members. The project duration was seven weeks long.

3.3 Education characteristics

Each team was required to document the design process in form of a journal [7]. The aim of this journal was to allow the students to self-report and keep track of all the difficulties they encountered and the solutions they came up with. To serve the purpose, the students were asked to use a blog-based website where they could document their ideation phase description, design process, and results supported by pictures and videos. This blog-based website allowed both the students and instructors to post, see and comment on the weekly submissions. Another requirement of the course was to reflect on prototype generation process.

3.4 Findings

By using the prototypes or outputs, journal documentation, and self-report, sustainability considerations are examined. This examination resulted in refined indicators and requirements. The sub-indicators during the prototyping phase concerns recycling, reusability, transportation, energy consumption, waste reduction, and emissions [8]. The three stages of design thinking process composed of *ideate, prototype*, and *test* have significant sustainability impact. Software and 3D simulations can be used during iterative improvement of design solution during ideation phase prior to physical prototyping. Early prototypes can be made using leftover or recycled materials.

4 HOUSING DESIGN COURSE

4.1 Overview

The Housing Design courses at Kyung Hee University are for two-course sequence over two semesters. These courses are used for the bachelor degree exhibition for the students in the Department of Housing and Interior Design [10]. Thus, the first course is taken by junior students and the second course, by senior students. As a part of the workshop of the SEDE-FAN project, the resulting states of the first course for student design teams were presented. At the time of this paper, the second course is being conducted.

4.2 Course structure

The teams are composed of 2 – 4 students each and 10 teams have been formed. The teams focus on the design problem understanding and design requirements identification. As Kyung Hee University joined the SEDE-FAN project, they introduced the focus on sustainability and all teams were required to identify their UN Sustainable Development Goals (SDG). Some of external lecturers were invited to give special lectures on green design and recycling service systems. The instructor also asked each student to declare their personal statement on sustainable life. The student teams designed building concept with considerations of the major activities of the residents of their choices. During the second course, student teams will address prototyping design and building in preparation of their graduation exhibition.

4.3 Education characteristics

Summary of 10 design teams is now provided. Team 1 aims at achieving SDG of 3-good health and well-being, 8-decent work and economic growth, and 15-life on land. They plan on designing eco-friendly co-housing using the slope of existing land to reduce the damage to the land without any underground development. The objective is to enhance ecological value of the landscape by creating linked green spaces. Their target residents are those with forest-related occupations and artist of nature. They plan to build eco-friendly co-housing. Team 2 focuses on SDG of 3-good health and well-being, 4-quality education, 10-mitigating inequality, 11-sustainable cities and communities. They plan to use slop roof form and rooftop garden to develop a specialized self-reliance preparation co-housing for 15 young people. Team 3 intents to achieve SDG of 3-good health and well-being and 12-responsible consumption and production. In order to create maximum green space, they plan to link surplus space with existing green areas, and community gardens for residents. They also plan to control the amount of sunshine with the awning and block sunlight in summer while making the best use of sunlight in winter. The main intent is community housing for the coexistence between young people and senior citizens.

Team 4 addresses SDG of 13-climate action and 14-life below water and life on land. They propose to use the roof as a rain gutter to clean the plastic and use it as living water, and to connect green areas inside and outside the land. The target residents are young beginners in society, and they plan to improve the environment and revitalize the region with the recycling of plastics by building community housing. Team 5 has selected SDG of 10-eliminating inequality and 11-sustainable cities and communities. They plan to generate electricity using solar power to use eco-friendly materials for their co-housing design for disabled residents. Team 6 focuses on SDG of 8-quality job and 10-reducing inequality. They plan to maximize ecological environment by creating continuous green areas within the site and induces a connection with external green areas to protect nature. They aim to create a healthy indoor air environment by allowing fresh outside air to flow well to the elderly through openable windows in a community housing building. Team 7 aims to address SDG 1-no poverty, 3-good health and well-being, and 4-quality education. They intend to design the building while saving the slope of the existing land to avoid excessive underground development. The building type is a group home for children, accommodating 12 children and 5 childcare teachers.

Team 8 focuses on SDG 3-good health and well-being and 11-sustainable cities and communities. They plan to manage water circulation, store and use rainwater through the central sunken garden. To protect the ecological environment, they aim to actively utilize green areas in the land and connect with animal and plant habitats in the surrounding mountains, focus on natural light and ventilation, and design for the consideration of socially underprivileged people in the house unit. The building type is multi-family housing for the elderly, accommodating senior citizens in single and two-person households living in existing old residential areas. Team 9 intents to achieve SDG 5-gender equality and 8-decent work and economic growth. They plan to design the building to induce user behavior and contribute to resource circulation and prevent problems caused by the absence of family members through shared spaces with neighbours. The building will be community housing suitable for single-parent households, accommodating 8 households with pre-schoolers/lower grades and parents, 16-20 people. Team 10 focuses SDG 3-health and well-being, 8-decent work for all ages, and ensuring sustainable consumption and production patterns. They plan to build welfare housing for the elderly engaged in farming activities where they can use natural light to save energy, use solar panels, collect rainwater, and reduce food waste by sharing among residents.

4.4 Findings

As the teams are still working toward prototype models in their efforts, it is still not yet mature to list up their findings. The instructor asked, at the early stage, each student to declare their personal statement on sustainable life. They plan to require more reflections from individual members of the teams by using various forms of surveys and open-ended notes.

5 COMPARISONS

The key features of the courses offered by the three universities are summarized in Table 1. University of Turku's course is a master level course. The primary goal of the course was to teach students design thinking methodologies with a minor emphasis on sustainability in comparison with the other two universities. The duration of the specific project addressed was five weeks and the main education characteristic was structured design methodologies. The main finding of the course for SEDE-FAN project is that there are three layers of activities, consumer's experience activities, student's design activities, and instructor's education activities and the specific activities of each layer. Also, confirmation of the proposed framework for representing and analysing these activities.

Table 1. 2022 Comparison of Three Sustainable Experience Design Courses in SEDE-FAN project

	University of Turku	**University of Oulu**	**Kyung Hee University**
Student level	Master	Bachelor	Bachelor
Primary Goal	Design Thinking	Prototype Fabrication	Housing Design
SDG Goal	Minor	Medium	Medium
Project Duration	5 Weeks	7 Weeks	2 Semesters
Special Characteristics	Structured Design Method	Blog-based Self-report (General)	Self-reflection (Personal Sustainability)
Main Findings	Three Layers of Activities & Framework for Activities	Sub-sustainability Indicators	Housing Design Requirements and Design Prototypes

University of Oulu's course aimed at providing bachelor level students with primary focus on developing design skills and knowledge for digital manufacturing process while promoting sustainability, in a digital fabrication environment. The sustainability design goal was of medium importance compared to other two universities. Students were required to complete their project by the end of seventh week of the phase two and the course had a blog-based self-report activity as its significant education characteristic while it addressed many general topics. The main finding from the course was sub-sustainability indicators for fabrication for prototype phase of design thinking.

Lastly, Kyung Hee University offered a bachelor level project-based two-course sequence with a primary learning goal of housing design education and its impact on the environment. The sustainability design goal was of medium importance compared to the other two universities. The project spanned over two semesters, and the education characteristic of the course was self-reflection with sustainable life. The main finding from the project so far was identification of housing design requirements. Note that the focus will be made in making prototype models for their exhibition in the second course.

6 DISCUSSIONS AND CONCLUSION

Based on the comparisons in Section 5 which demonstrated how different in what contexts these courses are, some mutual learning possibilities will be discussed in this section. University of Turku's course can learn from University of Oulu and Kyung Hee University about self-reflection so that it is applied in improving its learning goal of design thinking education as well as the minor goal of sustainability related understanding. University of Turku can learn about development and use of sustainability indicators from the course of University of Oulu. University of Oulu can learn from University of Turku about structured descriptions of student and educator activities and their relations. University of Oulu's course can learn from Kyung Hee University's course about using specific student reflection, for example, more specific sustainability related reflection surveys. University K's course will learn from University of Turku about structured design process issues and from University of Oulu on developing specific sustainability indicators as needed in housing design education. Specific immediate future work for the network is to devise a structured student reflection tool which can support specific design process steps so that both students and instructors can review their respective design and education activities from the perspectives of specific design process requirements or sustainability indicators. Improvements due to such a reflection tool can be compared with mutual efforts in using the tools in respective education contexts so that these findings can be transformed to broader education efforts.

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UNDERSTANDING AND CHALLENGING CLIMATE SKEPTIC ATTITUDES AMONG ENGINEERING STUDENTS THROUGH INTERACTIVE PEDAGOGY

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ABSTRACT

This paper investigates the prevalence of climate scepticism among 3rd year engineering students and seeks to understand how pedagogical interventions can be used to challenge climate sceptic views. This contribution follows a two-pronged approach to estimate the proportion of climate sceptic attitudes in the classroom, understand their root cause and, most importantly, develop pedagogical tools to challenge such views. The first part involved conducting two statement-based surveys to identify the prevalence of climate scepticism before and after pedagogical interventions. The second part discusses the effect of the use of interactive pedagogical methods to challenge climate scepticism and reduce potential conflict in the classroom. The goal of this research is to determine which pedagogical methods can contribute to changing attitudes towards climate scepticism among engineering students. Two surveys were given to 275 engineering students before and after several hours of lectures on sustainability theory and an interactive class exercise to challenge climate sceptical views. The results of the surveys showed that climate scepticism among our group of engineering students was higher than the Norwegian general population average and that the chosen pedagogical intervention showed mixed results in changing these attitudes. The results of the study can be used to understand how engineers perceive the challenge of climate change and to what extent engineering students are sceptical of climate change science. The results will also be useful for educators in understanding how topics of climate change can be discussed and how climate scepticism can be dealt with in the classroom through effective pedagogical methods.

Keywords: Climate scepticism, engineer students, interactive pedagogical methods

1 INTRODUCTION

Engineers play an important role in the sustainable transformation of societies and the development of technological capacities to address human caused climate change. It is therefore no surprise that modern engineering education is increasingly focusing on sustainable design and technical solutions for environmental problems. Engineering disciplines have an outsized influence on sustainable technological development, which means that an understanding and belief in climate science is critical to understanding how technology should work to reduce climate change impacts. It is therefore paramount for educators to understand which gaps in climate science knowledge exist, how prevalent climate scepticism is, and what pedagogical tools can be implemented to combat change scepticism. Educators need to understand the scale of the problem of climate scepticism among engineering students by understanding how their students perceive issues around the scientific foundation of climate science. This study seeks to discover the scale of climate scepticism among engineering students and takes a first step in developing a pedagogical intervention for changing attitudes towards more scientific based understanding of climate change. The study combines a survey approach with interactive pedagogical intervention. Drawing on research that tries to understand the impact of pedagogical interventions on students' attitudes towards science in general [1], this study utilized in-classroom interventions for undergraduate students in engineering at the University of Agder in Norway.

2 CLIMATE CHANGE SKEPTICISM IN EDUCATION

Even though there is a general consensus on the science behind anthropogenic climate change [2], climate sceptic attitudes are significantly high in western societies [3]. Within a broad political consensus, Norway aims to be an international climate leader, while at the same time paradoxically continuing to produce petroleum as the largest economic sector [4]. Climate change denial is not common in Norway; however, it is relatively common to hold sceptical views of the seriousness and impacts of climate change [5]. There is, however, not much data available on the attitudes of climate scepticism among engineering students in Norway, but a small body of research from engineering educators in the United States has also shown climate scepticism to be surprisingly prevalent there, especially among civil engineers [6, 7]. A similar study has shown that up to 30% of engineering students misunderstand the mechanisms behind climate change, but that the general belief in climate change science is higher than the average population in United States [8]. These studies, however, are geographically limited and do not reflect the attitudes of engineering students in Norway, or Europe in general.

As a topic for educators, addressing climate change poses two main challenges: First, the term is only vaguely defined and tends to lump together anti-scientific and anti-elitist sentiments with distinct normative and political convictions such as an aversion against regulative politics or distinct national(ist) views on international relations [12]. Second, since climate change sceptics often have a distanced relationship with "authorities" and proponents of "mainstream views" top-down attempts to "educate them" might reinforce their worldviews as opposed to changing them. Literature on Education for Sustainable Development [9] in schools suggests that there is a need to develop new holistic pedagogical strategies which we believe should also include teaching at universities. An interdisciplinary approach in teaching sustainability issues (in line with the UN Sustainable Development Goals) is needed for successful and holistic sustainable development to occur, but students must believe that these environmental and sustainability issues exist to foster change. It is therefore important to not only look at the students' technical understanding of the issues, but at how these issues relate to their attitudes and beliefs for understanding the complexities of their climate sceptical views. It is also important to avoid what can be perceived as a more "authoritarian" top-down lecture approach to combatting climate sceptic views, which can reinforce their climate sceptical views, especially when the lecturer is not perceived as a trusted figure.

3 METHODS

3.1 Test group

The course ING200 at the University of Agder, Norway, is a 3rd year course that is taken by all engineering students in the final semester of their bachelor's degree. The course is designed to help engineering students think in terms of systems and evaluate technology based on a foundation of ethics and sustainability, as learned in the course. The main course modules focus on systems thinking, scientific knowledge theory, ethics, sustainability, circular economy, and life cycle thinking for engineers. The class size is approximately 275 students per year and is a mix of engineering students who are studying degrees in construction, mechatronics, electronics, renewable energy, and information and communications technology (ICT).

3.2 Survey design and data collection

Two exploratory surveys were given to the ING200 students. The first survey was given early in the semester, before any sustainability theory was taught, to determine baseline attitudes towards sustainability, and more specifically climate scepticism. The exploratory survey was designed to map out the attitudes of the engineering students' beliefs and attitudes towards climate science. The survey presented statements regarding attitudes and trust towards climate science, policies, and the media which the students had to select their level of agreement with these statements. Questions about their basic demographics, motivation for studying engineering, and general beliefs about sustainability were also included. Following six hours of sustainability lectures and an active session in the classroom on climate scepticism, the students were again asked their overall opinion on sustainability issues and views on climate scepticism, including questions regarding which sessions they participated in in the classroom and if they believe their opinion has changed, how and why.

3.3 Pedagogical intervention

After the initial survey had confirmed the existence of climate change sceptic attitudes among the students, an in-class 45 minutes session was dedicated to exposing them to scientific information and accompanying explanation that addressed selected major talking points of dissenters of the (alleged) climate change “mainstream”. This session aimed to include interactive, participatory elements that give the students a say while respecting their (potentially dissenting) views. The session was aimed at starting a dialogue rather than enforcing specific interpretations of available information. Participating students were given the opportunity to reflect on the topics, give anonymous feedback and voice their opinion to their peers. This pedagogical intervention took place after the lectures on sustainability and were attended by approximately 65 students. Students were asked to work in small groups to engage with and discuss selected questions and materials covering three core reasons for disagreement on climate change: (1) the validity of climate science, (2) belief in a consensus on climate research and (3) media coverage of climate change. They were confronted with common climate sceptical statements such as (1) “*Climate science is not responsible. We simply do not know if the climate is changing*”, (2) “*there is no consensus on climate change amongst scientists*” and (3) “*traditional media doesn’t tell the truth about climate change*”. They worked with this step-by-step, getting one statement at time followed by curated information presenting different views, memes, news articles, opinion pieces and scientific sources on the validity of related research and opinions. The students discussed in groups with the researchers available for questions and listening in on discussions. After some group discussions, they answered questions anonymously in an online Mentimeter survey in the classroom before they started on the next statement. The responses came in as word clouds, ranking and open-ended responses, and these were used as data in this paper, in addition to the surveys prior and after the intervention. The intervention was thus dialogue based between the students themselves, and between the students and the researchers. They had the opportunity to write in anonymous individual answers in Mentimeter.

4 RESULTS AND DISCUSSION

4.1 Results from the first survey

The first survey had 82 respondents who completed the survey, with 83% being male, and 17% female. The majority of the students (38%) were enrolled in mechatronics, followed by ICT/IT (26%), construction and civil engineering (20%), and the rest (12%) were pursuing a degree in renewable energy.

The first survey established a “base line” by mapping the attitudes of the participants prior to any pedagogical intervention. When asked whether we are currently experiencing an environmental crisis (see Figure 1), the majority (68%) agreed or strongly agreed with only a small minority (2%) disagreed strongly or disagreed (9%), while 24% were neutral. However, the picture is less clear regarding trust in climate science: 11% of the students agreed or strongly agreed with the notion that there is no scientific consensus, 66% disagreed or strongly disagreed, while 23% were neutral.

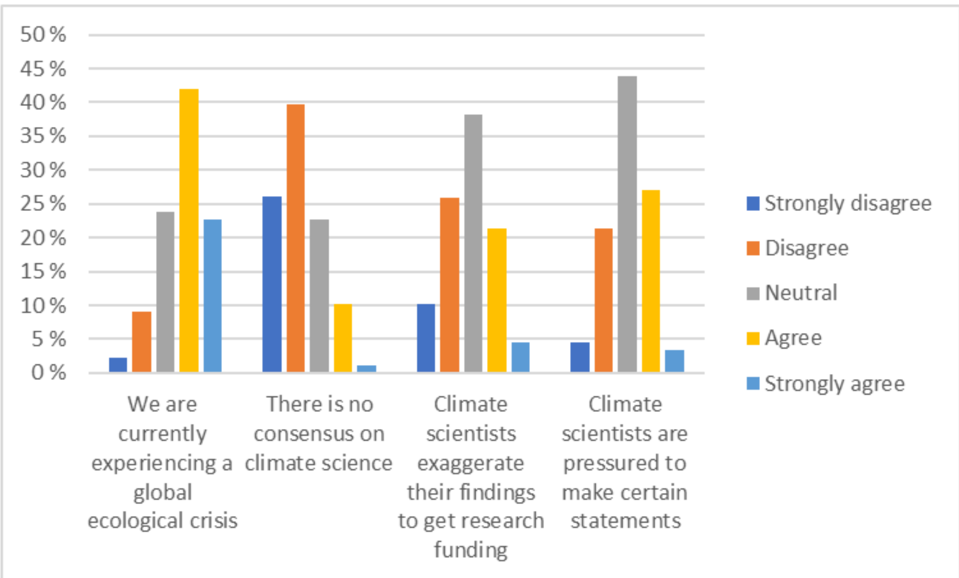

Figure 1. Regarding attitudes towards climate change and climate science

More than one third (36%) either strongly agree or agree with the statement that climate scientists exaggerate their findings to get more funding, and 25% agreed or strongly agreed that climate scientists are pressured to make certain statements demonstrating a more complex picture of the reasons why some of the respondents don't trust climate science. Despite a considerable reservation against climate science, it was surprising to learn that "sustainability" as a topic was overwhelmingly seen as important for the students and their personal lives as well (Figure 2). This suggests that climate scepticism attitudes and concern for the environment are not always mutually exclusive for this group of engineering students.

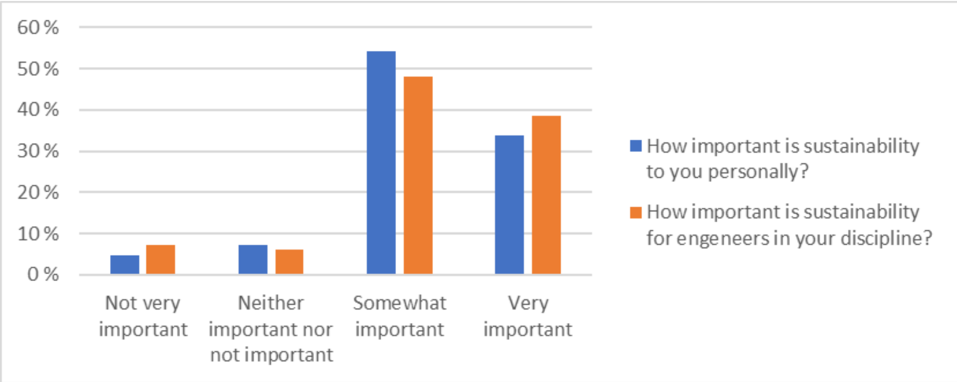

Figure 2. Importance of sustainability from the first survey

4.2 Pedagogical Intervention

The pedagogical intervention mainly aimed at questioning the students' beliefs on climate change. As a viable proxy for assessing the impact of the intervention, the students were asked whether they believed that they "know enough about climate change" before and after being exposed to carefully curated material in the in-class session that addressed the three main talking points of climate change deniers (as described in the methods section). As displayed below (Figure 3), confidence in personal knowledge *declined.* Since the pedagogical material did not include any information that justifies or amplifies climate science or climate policy scepticism the results are likely indicate the beginning of a questioning of climate sceptic views.

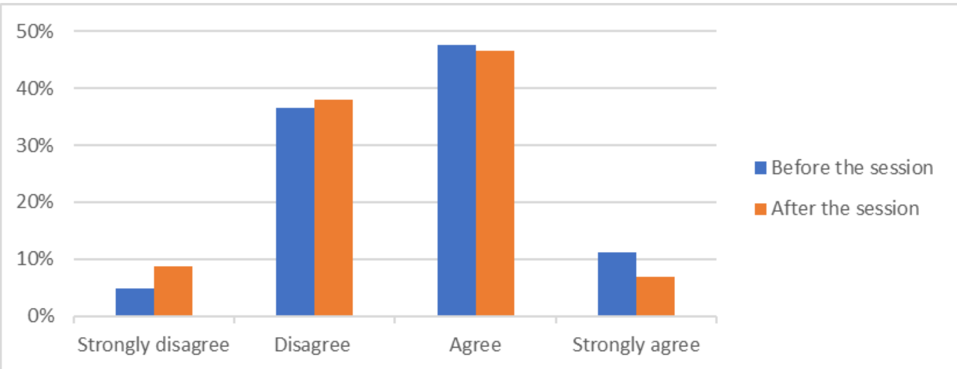

Figure 3. Response to question "I know enough about climate change" before and after in-class intervention

Figure 4 shows the average of the class from 1 (strongly disagree) to 4 (strongly agree), meaning 2,5 is the "medium" in this specific ranking exercise. The average was all around the "medium" or "neutral". When contrasted with the findings from the online survey, these findings paint a differentiated picture showing not only *that* a considerable share of students reject the consensus on climate *science* but *why*.

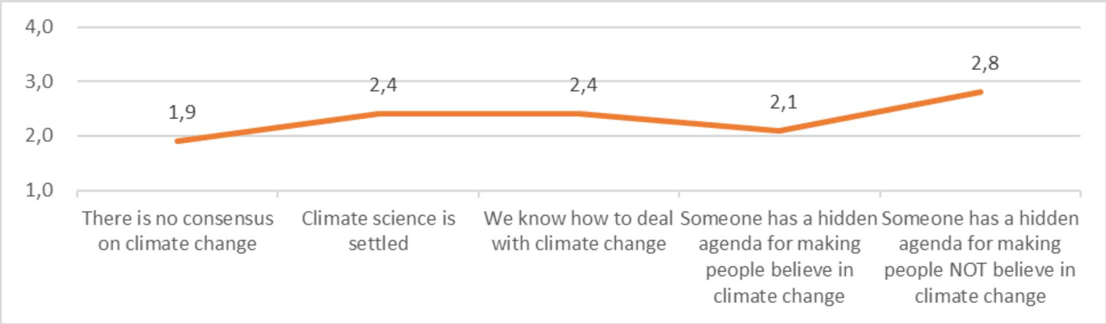

Figure 4. Regarding beliefs in climate science. The figure presents the average in the class

4.3 Results from second survey (post-intervention)

The second survey had 58 respondents who completed the survey, with 79% being male, and 21% female. The majority of the students (40%) were enrolled in mechatronics, followed by ICT/IT (28%), construction and civil engineering (22%), and the rest (5%) were pursuing a degree in renewable energy, which is a slightly different mix of students than the first survey. The second survey was given after the in-class session and revealed a more mixed impact from the chosen pedagogical intervention. While 12 per cent of the students stated they had become less sceptical because of the materials and explanations they were confronted with in the course, an almost similar share (11%) reported that their reservations to accept climate science had increased, while another 9% of previously sceptic students had unchanged beliefs. These findings could be explained by research in increasingly disconnected “counter publics” [10] which are increasingly unwilling to accept information that challenge their normative convictions and knowledge about climate change [11]. This could also be that the respondent groups were not identical between the first and second surveys.

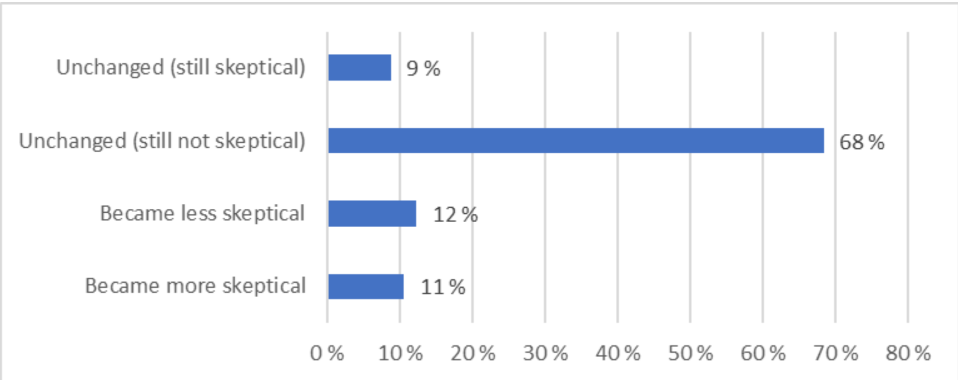

Figure 5. from the second survey, on the effects of the pedagogical intervention

There was also an issue that some respondents wrote unserious replies during the didactical intervention. This also seems be the case with the second survey, as some answered how the pedagogical session influenced them, even though many of them did not participate in the session. The respondents from the first and second survey are not necessarily the same people, and the validity of especially Figure 5 needs to be researched further. To tackle these challenges, future research would include sending the survey to other institutions, looking at different disciplines for a comparative study and trying out different pedagogical interventions. The study was also limited by the time available for the intervention, with only 45 minutes for the in-class session, and a few weeks between the first and the second survey. A longer period between the surveys or longer time in the classroom would potentially provide more conclusive results.

5 CONCLUSIONS

The results of this study show that a considerable share of engineering students hold climate science sceptic views, above the Norwegian national average. When given the opportunity to engage in a guided debate about climate change and when confronted with selected materials on the scientific research, decision making and communication about human made climate change, students begin to question whether they “know enough” thus indicating a possible opening for pedagogical interventions to tackle climate sceptic views. The subsequent second survey, however, points to the limits of classical pedagogical approaches which focus on the dissemination of information and the provision of explanation. While the didactive intervention produced mixes results, this study not only shows that climate sceptic opinions are endemic among engineering students but that challenging them requires active, participatory, and inclusive learning techniques that refrain from top-down lecturing and attempts to simply disprove students who hold dissenting views. The results of this study show that there is a need for further intervention among educators for guiding engineers towards a sustainable future. To expand the research, more time and more sessions would be beneficial. We suggest that varied and interactive approaches to both learn about climate change and facilitate an arena where the students' opinions can be explored and challenged can contribute to this complex issue, and that more research using different pedagogical approaches is needed.

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CAD BASH: ACCELERATING 2D/3D COMPUTER AIDED DESIGN COMPETENCIES FOR FIRST YEAR PRODUCT DESIGN STUDENTS

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ABSTRACT
The everchanging technological/digital landscape of the Product Design (PD) and Product Design Engineering (PDE) industry now requires graduates to have a wider range of software skills/knowledge. In particular, there is a need for enhanced skills focused on engineering computer aided design (CAD), virtual reality, 3D visualisation and rendering/animation. This has resulted in graduates requiring a more detailed/rigorous CAD/3D visualisation syllabus to prepare them for industry. With the increased pressures on delivering a wider range of software teaching alongside a greater range of hardware, the need for a good grounding/understanding of 2D/3D engineering CAD competencies is essential. The PD Department at Nottingham Trent University (NTU) identified the need for enhanced engineering CAD teaching/learning within the higher education setting, especially within the first-year PD curriculum. There is the need to challenge established pedagogy and delivery methods with regards to CAD tuition and explore new delivery methods and alternative educational paradigms to allow educators to equip engineers/designers for future industry requirements. This paper explores the development of 'CAD Bash', an accelerated taught SolidWorks 3D CAD syllabus delivered to students in a five-day synchronous format and supported by asynchronous content. CAD Bash was delivered in week two of the first-year BSc Product Design curriculum to sixty-two students. Students perceived skill set was assessed through a skills audit pre and post CAD Bash. This paper presents the findings from CAD Bash and the learner and academic insights with recommendations made regarding its future delivery.

Keywords: 2D/3D visualisation & communication, Computer Aided Design (CAD), CAD training & competencies, product design education, skills audit

1 INTRODUCTION

Computer Aided Design (CAD) has become one of the essential parts of design education in higher education (HE) [1], especially within UK PD courses [2]. However, in recent years scholars have been exploring alternative ways to deliver CAD sessions, whether this be through project-based learning due to the impact of COVID-19 [3] or by exploring approaches to allow students to be more successful attaining professional accreditations i.e., Certified SolidWorks Associate/Professional (CSWA/CSWP) [4]. It can also be argued that learning more than one 3D CAD software package is essential [5] within design/engineering education considering the demands of modern-day manufacturing and the blend of disciplines many industry roles now require. Furthermore, the demand from industry also requires graduates to have a greater understanding of the wider industry needs/requirements especially in relation to sustainability implications [6], the circular economy, digital manufacturing etc. As such, PD education needs to adapt to ensure students understand how to use complex features within software packages such as life cycle assessments, but first students must fully understand the fundamentals.

At NTU, weekly engineering 'CAD Lab' tuition has been adopted for undergraduate instruction and progression for many years. Sessions typically last for 90 minutes across all undergraduate PD courses with varying 26-week syllabi across year groups. In recent years it has been discovered that student attainment, and engagement has been wavering, in some instances leading to absenteeism, and deficits in proficiencies. Whether this was due to changing student profiles, and the way in which they learn, or assumptions by tutors that they would practice outside of the classroom to catch up on anything that had troubled them, it was necessary to discover a way to inject both a level of competency and engender methodologies of approach that could lead to increased engagement, which in turn, allow the students to 'hit the deck running'. At NTU, we deliver teaching across a suite of software programs that aligns to industry partners and design practices with CAD tuition running concurrently with design studio projects. Delivered content allows students to prepare/achieve CSWA/CSWP within the curriculum; it is widely accepted that this benefits and adds value to a student's CV and subsequent graduate employment [7]. Historically, the expected outputs from projects had to be tempered to match the levels of vocational and technical knowledge. Typically, this meant that CAD modelling and visualization within the first year was modest as students went through increasing levels of proficiency. To counter any ennui as the result of the slow climb to competency, it was hypothesized that a 'kick start' from the outset was necessary to allow new first year students to see the potential of industrial practices early on, whilst 'upskilling' them quickly. As such, 'CAD Bash' was developed.

2 CAD BASH & LOGISTICS

The premise of CAD Bash was to employ a new strategy for up skilling first year PD students, to enable rapid progression and positive association within engineering CAD. CAD Bash was designed to complement a weekly design sketching syllabus that introduces engineering drawing principals and supporting studio sessions where engineering drawing interpretation is taught. This pilot program was run with BSc PD students in the second week of the first academic semester. CAD Bash is an accelerated program of eight 1.5/2-hour engineering CAD sessions, held over a five-day period that seeks to give a broad overview of essential approaches/practices. This raised several logistical planning challenges for a cohort size of sixty-two students. At NTU our pedagogic approach suggests that student group sizes in taught CAD sessions should not exceed a maximum of 25 students with one lead academic and a supporting colleague. Increasing CAD class sizes beyond this often resulted in retention and attainment issues. With only five CAD facilities available with the required software, each of which varies in size, this posed a logistical challenge regarding group sizes. As such three groups of 20-21 students were setup with two academic colleagues always present. Often due to timetabling restrictions CAD Bash sessions would run concurrently and as such up to six academic colleagues were required to run the concurrent sessions. The student profile also highlighted students with various learning access statements and physical and digital accessibility requirements. These factors needed to be considered within room allocation and tutor allocation. A critical aspect of the curriculum was ensuring all academic staff were well versed in the syllabus, ensuring consistency in delivery, across the resources.

2.1 Logistics & Content Creation

Vocational lead (Paul Kennea), an academic with over two decades of experience teaching and devising CAD syllabi, developed the CAD Bash approach. The CAD Bash format of delivery was a five-day synchronous course supported by asynchronous content. This asynchronous content was recorded educational videos of the sessions supported by eight PDF instructional documents. Video content produced was a means of backing up the in class taught content; this provided the students with a resource to refer to during or post sessions. These videos allowed academic colleagues to review/deliver the same approach, to ensure consistency and alignment. The content focused on developing 'best practice' providing a solid foundation to build upon. It was key that students understood the parametric hierarchies of SolidWorks, to establish and drive good practice. Content needed to be NQF Level 4 relevant, and as such technical tuition was delivered in a manner that was clear to students, adopting an iterative approach, starting simple, and slowly building in complexity, through simple tools. The purpose of the syllabus was to provide students with the skills to build accurate 3D models, singular or multipart assemblies, and then produce elevational technical drawings. At every stage it was key to maintain an industrial bias, whilst at the same time not unnecessarily overwhelming students who are often naïve to the process. Critical to all the activities was to develop independent thinking and embed an approach akin to that used within industry. Activities started with fairly simple extruded and revolved forms, increasing complexity through sketch work (driving extrusions and revolves), and technical sheet layout.

2.2 CAD Bash Sessions & Structure

CAD Bash was structured into eight separate sessions with distinctive learning outcomes and topics assigned. Session 1 focused on introducing SolidWorks, the software interface, the production of basic sketches/elevations and sketch relationships/parameters. Session 2 focused on rotational and revolving entities within 2D & 3D sketches alongside dimensioning. Session 3 explored sketches with extruded boss/bases and creating a 3D part from a 'nested' sketch using selected contours. Session 4 explored more complex sketches and sketch relationships, alongside 3D feature commands such boss/base extrude, shell and hole wizard. Session 5 explored revolve boss/base features and understanding drawing conventions. Session 6 focused on drawing tools by creating technical drawings which clearly define and convey all the necessary technical information derived from SolidWorks modelling. Session 7 explored the creation of 3D components with the restriction of specific 3D features/tools such as revolve and revolved cut boss/base. This session also introduced basic assemblies and the production of general assembly (GA) drawings with content derived from modelling parameters and properties. Finally, Session 8 explored assemblies/sub-assemblies by assembling a Lego Figure and Lego Fire Boat.

During the first few sessions, students were introduced to the SolidWorks interface, and the first stage of CAD development i.e., sketch/2D Drawing. Tuition on how 'sketch tools' worked, allowed the teaching of defining sketches through a fixed datum. After experimenting with sketching, students undertook a quiz with six key questions challenging them to draw and full define sketches (Figure 1).

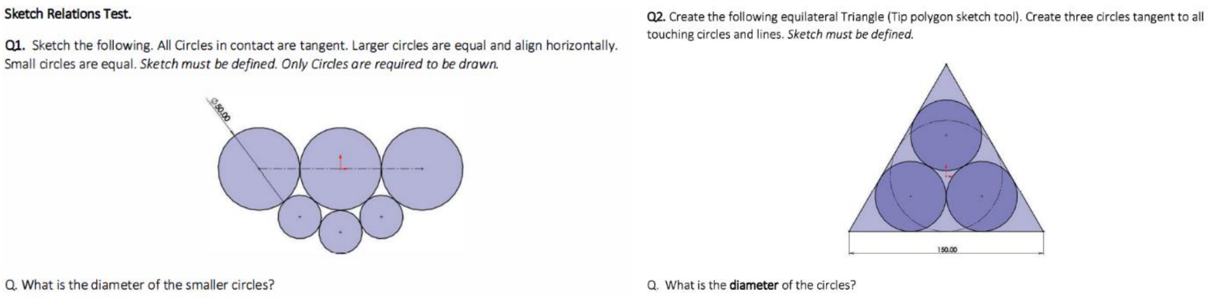

Figure 1. Examples of Sketch Relations Questions

This quiz was designed to check the students learning in relation to their familiarity with sketch tools, their understanding of construction approaches and defining through 'relations', dimensions, and datum. This helped to establish the 'rules of engagement' at an early stage when using sketch tools i.e., sketch then define (both sketch relationships and dimensions), and anchor to a datum. Later tasks (Figure 2) reinforced approaches to define sketched forms before exploring 3D forms.

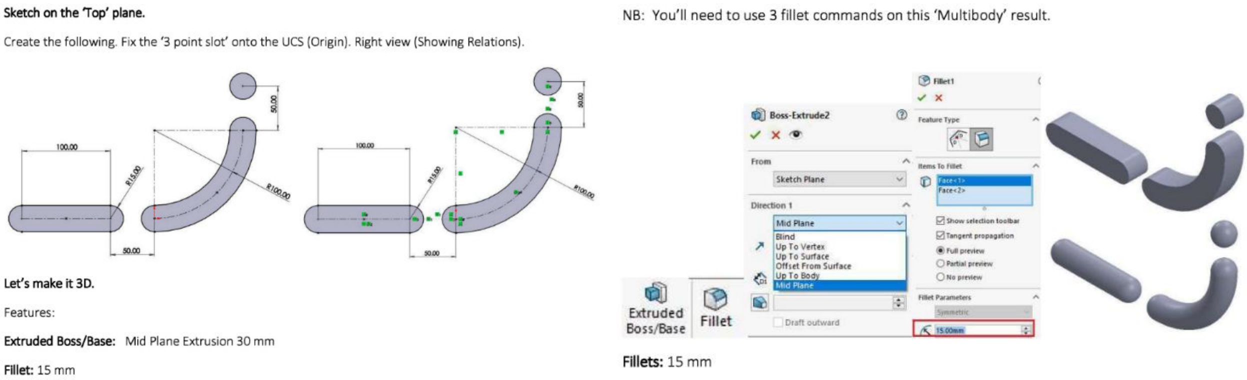

Figure 2. Examples of Sketch Relations Questions

Later sessions challenged students to understand the logical ordering of steps to accomplish a given task (Figure 3). Typically, the examples presented in the sessions fully explained the modelling methodologies by breaking it down step by step. This was supported by handouts with text explanation and screen shots and further enhanced by the accessible in session videos. Subsequent questions/activities followed a similar process; however, students were then supplied with only technical elevations of a form/product, with the expectation that they use the learnt methodologies to produce the correct CAD output. Again, if a student struggled, tutors and videos would help them resolve any issues. It was found that in most cases, students enjoyed the challenge; several students didn't require video support (22%), though at times still sought guidance from the teaching staff. By the start of Session 4 the students had completed 4.5 hours of SolidWorks tuition. Prior to the start of CAD Bash, typically 80-90% of students were previously unfamiliar with the application; within this cohort 83% of students had never used SolidWorks before. Session four whilst using simple tools, starts to challenge the students by bringing complexity through technical annotation, and designed features. Again, whilst this was fully broken down by a step-by-step approach, additional/new approaches and tools were introduced, including the use of feature wizards (Figure 4).

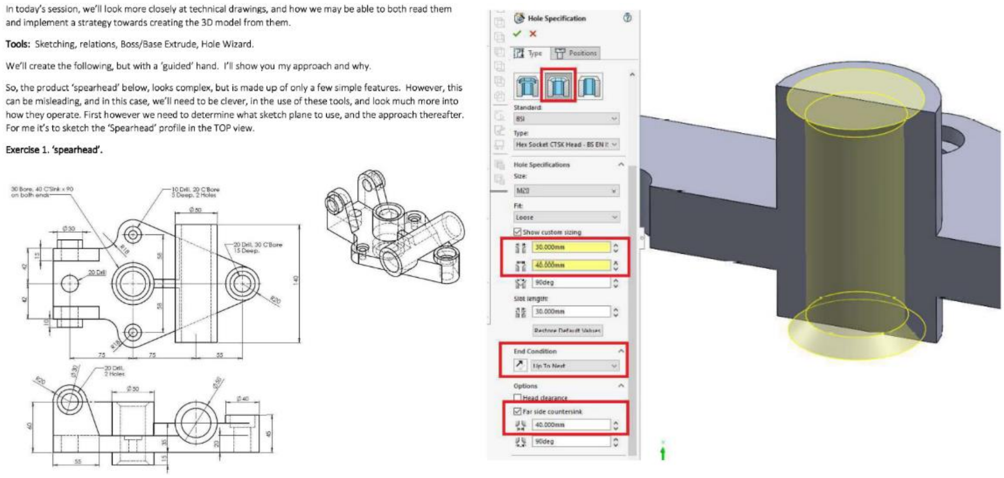

Figure 3. Wedge Lift Activity Step By Step (Left); Wedge Lift Activity Reference Drawing (Right)

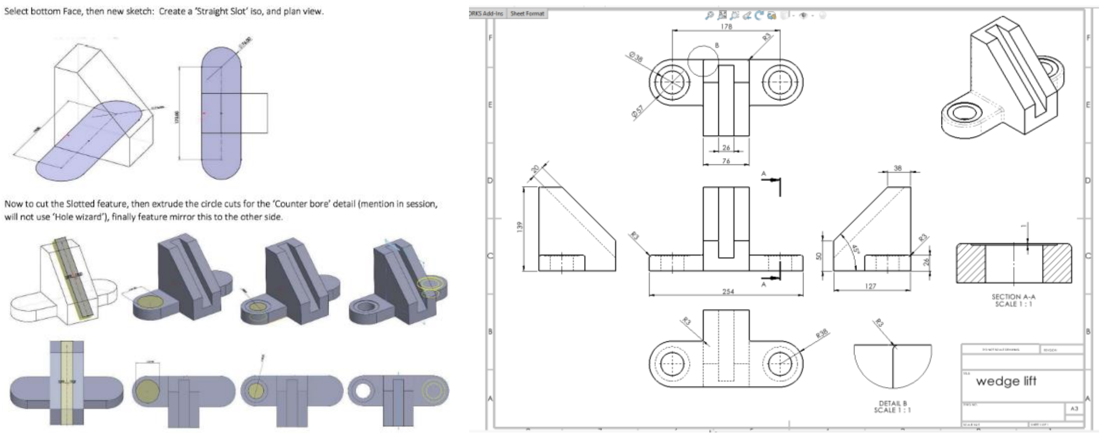

Figure 4. Technical Elevation Worksheet (Left); Hole Wizard Feature Using Derived Values (Right)

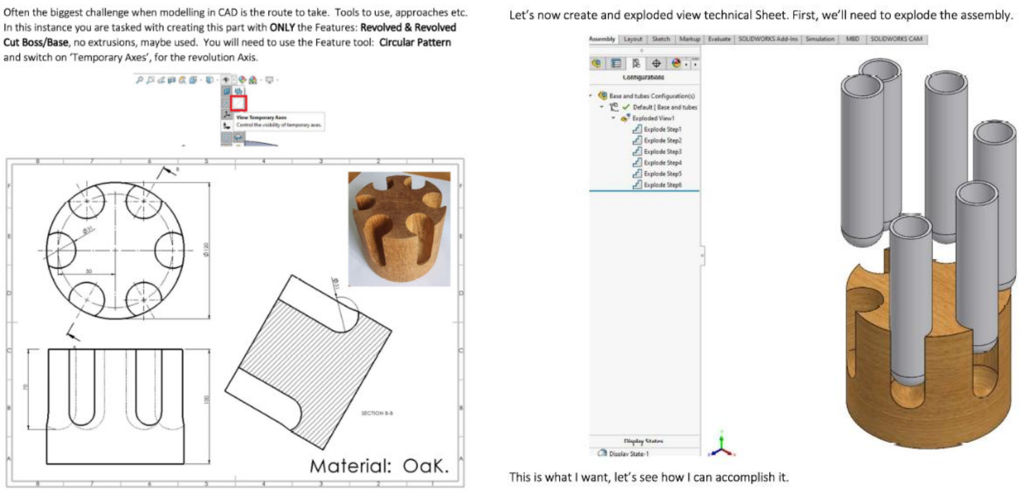

Figure 5. Technical Elevation Worksheet Featuring Revolved Features & Assemblies

By Session 7, students were now showing a very good level of independence, using critical approaches to interrogate technical elevation drawings and produce varying 2D/3D forms in SolidWorks. As such Session 7 now 'throws a spanner in the works' by challenging the students to model using restricted features. Students are faced with questions such as "What if you are unable to use an approach that seemed the simplest?" Figure 5 shows an imposed limitation the students were presented with, requiring them to create a form using only the revolve tools before then being challenged with exploded views, sub-assemblies, and assembly tasks for the first time.

3 METHODS

To enhance the CAD skills of PD students, the PD academic team delivered an accelerated 2D/3D engineering CAD syllabus focused on core competencies within first year by providing a learning program focussed on SolidWorks. This teaching block of 2D/3D engineering CAD, utilizing SolidWorks, was delivered in week two of the first-year PD students higher education journey. Sixty-Two BSc PD first year students undertook eight 1.5-2-hour sessions over the course of a 15-hour accelerated synchronous teaching block during a single week. CAD Bash synchronous teaching was also supported by asynchronous content in the form of pre-recorded videos and prepared worksheets/guides. Students receive 6 hours of taught content on Monday, 1.5 hours on Tuesday, 1.5 hours on Wednesday, 4 hours on Thursday and 2 hours on Friday.

Prior to commencing 'CAD Bash', each student completed a Pre-CAD Bash skills audit using a 5-point Likert Scale approach delivered through Microsoft Forms. The questions asked were designed to ascertain the student cohorts' current knowledge/understanding of software programs, situated within Engineering CAD, such as SolidWorks as well as exploring general CAD competencies. Historical data was also collected to ascertain prior knowledge on CAD software in addition to demographic data. This survey helped inform the tutors on student prior knowledge allowing adjustments to the level of learning/content delivered. A Post-CAD Bash skills audit was then collected using the same 5-point Likert Scale approach delivered through Microsoft Forms. This data provided insight into the effectiveness of the accelerated teaching block, thus informing CAD tuition for the remainder of the academic year. Student feedback and the findings from CAD Bash was ultimately collected to demonstrate the effectiveness and impact of an accelerated CAD teaching block focused on fundamental engineering CAD competencies. Fifty-two students completed the pre and post CAD Bash survey (response rate of 83.4%); a summary of the key results and findings are presented in section 4.

4 RESULTS & FINDINGS

As demonstrated in Figures 6 and 7, CAD Bash has elevated student core competencies and CAD proficiency significantly within five days. Notably, 92.3% of students agree or strongly agreed with the fact they are confident in using the SolidWorks interface, with no negative responses provided.

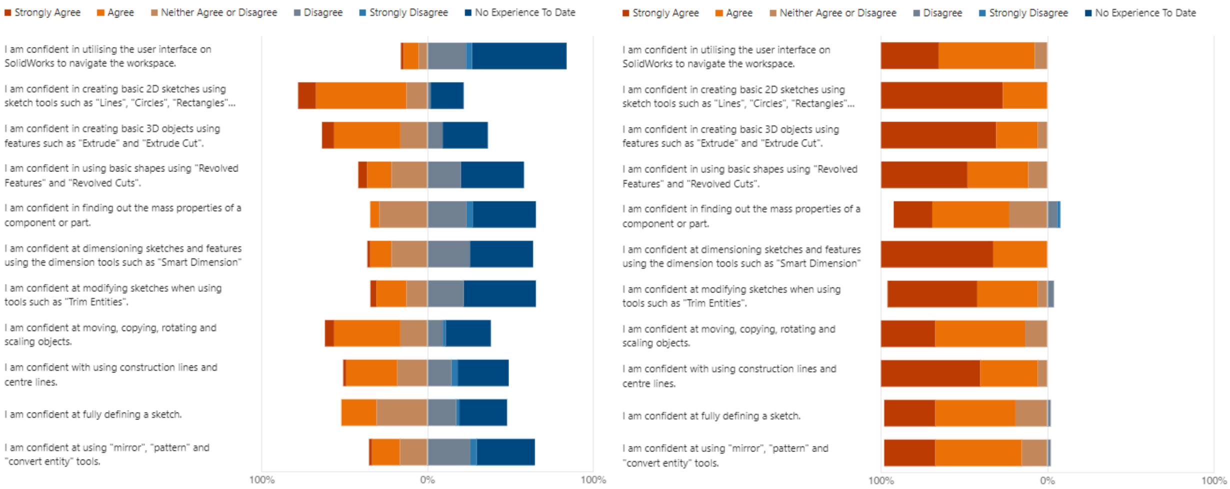

Figure 6. Sketch Tools: Pre CAD Bash-Skills Audit (Left); Post CAD Bash-Skill Audit (Right)

Within the core sketch competencies/commands all areas drastically improved, and of note only a few students still had negative responses to the skills audit questions regarding specific features (mass properties: 7.7%; trim tools: 3.8%, sketch definition: 1.9% and mirror, pattern and convert entity tools: 1.9%). In the use of the more advanced tools most students made significant progress, however with more complex features tools such as lofts (19.2%), sweeps (21.2%) and editing bodies (i.e., splits, combine: 19.2%) felt that they needed more support/tuition on this. A small number of students highlighted the need for some additional support on hole wizard (5.8%), technical drawings (7.7%) and assemblies (7.7%).

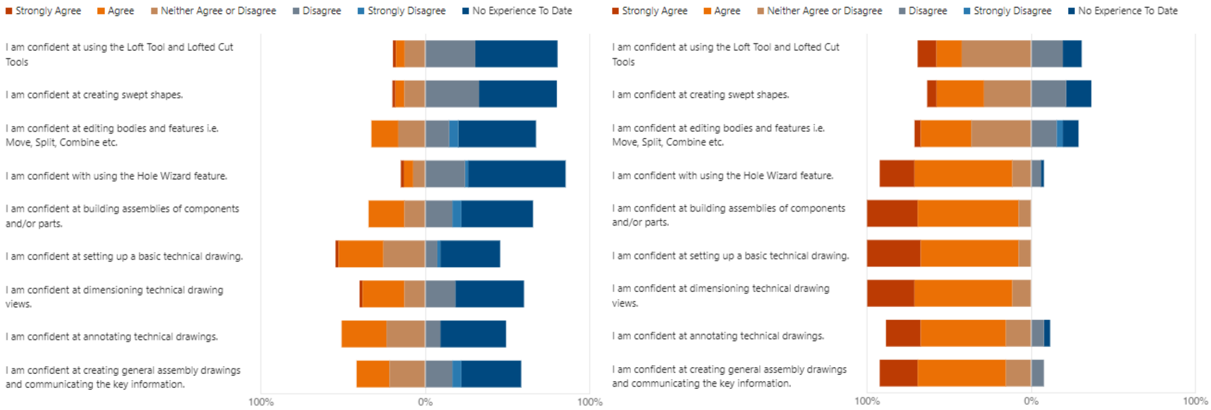

Figure 7. Features & Outputs: Pre CAD Bash-Skills Audit (Left); Post CAD Bash-Skill Audit (Right)

The overall rating of CAD Bash for the week was 4.54/5 with all but two respondents providing a 4-or-5-star rating for their rating of the CAD Bash experience. Limited negative feedback was provided; a few comments regarding hardware/software issues experienced early on and students noting the speed of certain sessions being a little fast for them. Overall, the development and deployment of CAD Bash was a huge success with the vast majority of feedback from students being overwhelmingly positive:

Overall, it was a great experience in order to help to understand the fundamentals of CAD (P2)

In my opinion, CAD Bash was taught very well and has definitely made me more confident while using SolidWorks. I didn't really see any negatives. (P23)

5 CONCLUSIONS & RECCOMENDATIONS

From the feedback small changes are necessary such as providing further resources to those students who excelled/completed the sessions quicker than expected. No demographic or nationality issues were noted; international students identified that the videos with captions and handouts helped with any confusion around terminology. Logistically CAD Bash is a significant challenge to organize, however we are currently exploring how we can use the CAD Bash model for other software. We also aim to explore how more complex modelling tools such as ‘Lofts’ and ‘Sweeps’ can be better integrated into CAD Bash. The deployment of CAD Bash demonstrated how the delivery of an entire term’s worth of CAD tuition within a single week prepared students better for future CAD learning but also created room within the CAD syllabus to teach more complex classes. This has enhanced our entire three-year CAD syllabus for PD students, positively impacting student skill level. Enhanced CAD skills delivered in an accelerated syllabus also offers increased placement/graduate opportunities too. Furthermore, a larger proportion of the cohort compared with previous years have since acquired Certified SolidWorks Associate status with a small number also achieving Certified SolidWorks Professional status.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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UTILISING HACKATHONS TO ENHANCE THE DESIGN PROCESS FOR ELECTRONICS & PROGRAMMING LEARNING WITHIN PRODUCT DESIGN EDUCATION

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ABSTRACT
The demand for enhanced technical competencies in graduates of product design (PD) and product design engineering (PDE) courses continues to grow year on year, with industry now requiring students to not only have an appreciation of design and manufacturing, but also a practical understanding of electronics and programming. However, traditional electronics and programming education, especially in product design courses, is often received negatively by students, especially by students that are solely driven by the creative aspects of the industry. At Nottingham Trent University (NTU), we identified that students saw a disconnect between their design education and their electronics and programming teaching and learning, yet there was a desire to understand more about how products function. Within the BSc Product Design course at NTU, there was a desire by the academic team to explore different pedagogies that would have a positive impact on electronics and programming learning, whilst also helping students see a more direct connection with this topic in relation to their future employment. As such, we sought to leverage the use of hackathons to provide an intense practical delivery approach for electronics and programming learning, whilst combining this with a focussed design activity. This paper explores the process of developing hackathons to complement electronics/programming curricula by encouraging students to combine all their skills in a product design context. Student feedback is presented based on their learning experiences. The paper concludes with a series of recommendations for the future use of “Hackathons” in product design education to help engage students.

Keywords: Coding, electronics & programming, hackathons, intuitive design, product design education

1 INTRODUCTION
Hackathons are short events, usually one to three days in length, where participants motivated by a common challenge work in groups to build a software or hardware prototype/output [1-2]. The hackathon methodology often focusses on specific design challenges linked to software or hardware development with the aim of realising a new functional outcome. Hackathons have been utilised in software engineering education for many years [3] and are typically utilised as a method of rapidly designing mock-ups, prototypes, or solutions which aim to solve a very specific goal or brief. Hackathons have also been utilised within the product design and engineering education realm as a form of design exploration [4], for design research [5], for project-based learning [6] and for technology focussed, business focussed, and social issue driven challenges [7]. Hackathons provide an opportunity to engage students in quick paced, experiential learning approach with the ultimate target of having a suitable outcome that is presentable. Hackathons present challenging workloads for students, as such cultivating the desired environment either online or face-to-face is important.

This paper explores the process of developing an electronics and programming curriculum that encourages students to explore the realms of the subject within a product design context whilst engaging with hackathons. The aim of this research was to investigate how the Hackathon methodology could be applied and to test whether this has any impact in the product design education curriculum. Furthermore, this research sought to investigate whether it was possible for students to apply their sketching, CAD, electronic and mechanics learning into one piece of work. This paper also explores the implementation of hackathons, identifying successes and challenges of using the methodology. This paper presents collected student feedback and is reviewed based on the learning experience for product design students with aim of implementing hackathons into the curriculum. Industrial partners have also identified the relevance of the activity in relation to a student's degree and future career/professional practices.

2 INTEGRATING HACKATHONS INTO THE PD CURRICULUM

At NTU, we integrated our first single day hackathon into the BSc Product Design course at the end of the 2020/21 academic year in an attempt to help students contextualise and apply electronics and programming learning into a product design focused outcome. This hackathon was received positively by students allowing them to connect their electronics/programming learning from their taught sessions via a focussed design challenge. Subsequently, in 2021/22 academic year our first two-day hackathon was implemented, whereby student groups competed against each other and were set the challenge to design, manufacture, and programme a remote-control vehicle (RC vehicle) using Arduino kits. The developed range of RC vehicles were then judged on their aesthetic design, quality of manufacturing and programming before being ranked based upon their ability to navigate a predetermined time trial course. The development of the hackathons and electronics curriculum is discussed below:

2.1 Electronics Curriculum Re-Development & Initial Hackathon

Due to the impact of the COVID-19 pandemic the traditional first year ten-week electronics syllabus had to be redesigned. As such this was split into two elements. Firstly, all students were provided with an electronics and Arduino kit on loan from NTU. Each student was required to complete a series of curated LinkedIn learning courses which were supplemented by academic recorded asynchronous online Tinker CAD videos/activities. Adherence to this program of work was extremely variable, with novice electronics users/students citing significant struggles. Second, the students were provided with six weeks/sessions of socially distanced classes on the development of simple circuits, an introduction to Arduino, basic programming, digital inputs/outputs, analog inputs/outputs, and motor drivers. To check student learning on the taught blended electronics/programming content, a one-day hackathon was developed. The hackathon focused on students working in groups of three or four and were tasked with designing, building, testing, and racing a designed cardboard vehicle which utilizes basic Arduino kits and motors. Size parameters were set for the vehicles. The judging/racing criteria was as follows:

1. **Quality Of Build & Aesthetic Appeal:** The cars were judged and ranked first to last based on the quality of the construction and its aesthetic appeal and use of additional electronic components to elevate the designed vehicles appearance/performance i.e., flashing lights, head lights, audio, etc.
2. **Speed Challenge:** A straight line race of the vehicles was conducted in a round robin system whereby vehicles were ranked first to last place based on the number of races won.

2.2 Expanding The Electronics Curriculum & Developing A Two-Day Hackathon

In response to the return of face-to-face teaching, the electronics curriculum was refreshed and increased to sixteen weeks of electronics and programming classes in groups of 15-18 students. This was broken down into six weeks of introductory electronics classes exploring fundamentals such as breadboards, soldering, simple circuits, and the use of multimeters. Ten weeks were dedicated to the teaching of programming microcontrollers (Arduino) and exploring topics such as motor control, sensors, switches, inputs/outputs, pulse width modulation etc. Based on feedback from students from the 2020/21 academic year a more challenging hackathon was developed and run over two days. The possibility of running a more challenging hackathon with a greater number of elements was possible due to absence of COVID-19 restrictions. The hackathon challenged student groups of three/four members to design, build, test, and race a wired robot controlled (RC) vehicle which utilises Arduino kits and motors/motor drivers. Students were required to use Arduino kits to control the directional control of the designed vehicle. This challenge allowed the students to put into practice the previous sixteen weeks of electronics and programming learning as well as implement the learnings from the eight-week mechanics curriculum too. The hackathon challenge required students to produce vehicles of set size parameters using 2-4 wheels. The students needed to balance the creative development of their vehicle alongside the functional performance and were judged based on the following criteria:

1. **Quality Of Construction & Electronic Capabilities:** The designed RC vehicles were judged and ranked first to last based on the quality of its construction and the vehicles electronics capabilities.

As such the student groups needed were required to use the electronics available to increase the overall aesthetics/function of the designed vehicle i.e., flashing lights, head lights, audio etc.

2. **Aesthetic Appeal & Creativity:** Students vehicles were ranked first to last based on the RC vehicles aesthetic appeal and creativity. They were challenged not to just build a car, but explore other vehicles that could developed, built and tested whilst not compromising functional performance.
3. **Obstacle Course Time Trial Challenge:** The RC vehicles were time trialled over an obstacle course which included ramps, multiple terrains, and several obstacles whereby the vehicles are ranked first to last based on the finishing time achieved. Missing obstacles, skipping obstacles, or removing obstacles resulted in pre-determined time penalties based on the course.

3 METHODS

Forty students took part in the forty-eight-hour hackathon at the end of the 2021/22 academic year. Students were split into groups of three/four and tasked with designing, building, testing, and racing the designed wired robot controlled (RC) vehicle which utilizes Arduino kits and motors/motor drivers. The student group with the highest number of points based on the rankings of the determined criteria would be crowned the winner of the hackathon and provided with a small prize to help further their electronic and programming learning. Post the hackathon judging, thirty-two students (response rate of 80%) voluntarily completed an end of hackathon survey which was constructed of twenty-four questions comprising of basic demographic questions, open-ended feedback questions, 5-point Likert Scale questions and overall event rating questions. This survey was delivered through Microsoft Forms. The collected data provided insight into the effectiveness of the hackathon teaching and learning approach. Student feedback and the findings from the hackathon were ultimately collected to demonstrate the effectiveness/impact of combining the students design, manufacturing, CAD, electronics, programming, and teamwork skills. A summary of the key results and findings are presented in section four.

4 RESULTS

The winner of the first hackathon challenge in 2020/21 was the group that got the highest combined score from the two challenges; examples of produced vehicles can be seen in Figure 1. Student feedback from the first set of hackathons was overwhelmingly positive with all groups able to produce functional vehicles. The hackathon helped underpin the taught electronics and programming content and provided a basis for the electronics and programming work to be completed in year two alongside industry partners; this is based on the development of electronic vehicles using modules. The winners of the second set of hackathons, run in 2021/22, demonstrated a higher level of electronics and programming skill as well as increased manufacturing and electronic integration (Figure 2).

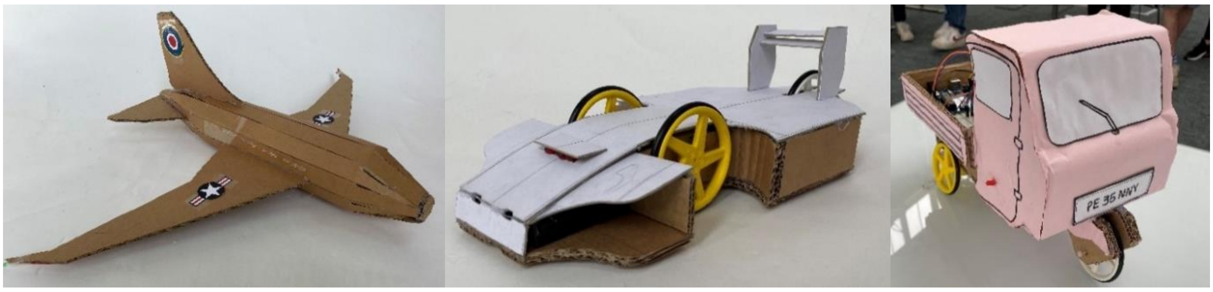

Figure 1. Assortment of developed Arduino vehicles during the one hackathon

Figure 2. Assortment of developed RC vehicles during the two-day hackathon

Feedback from the student survey presented to the 2021/22 cohort identified that only four students had taken part in a hackathon before. Prior to undertaking the hackathon, students identified how interested they were to learn about and experience a hackathon; seven students stated they were ‘extremely interested’, twelve ‘mostly interested’, ten ‘moderately interested’, two ‘slightly interested’ and one ‘not interested at all’. Student groups identified that they spent a variable amount of time working on the hackathon challenge, typically identifying that they spent 9-12 hours or 13-16 hours engaging with the activity. However, other students identified that they spent 20+ hours engaging with the hackathon. Collected student feedback highlighted several areas that they found useful when undertaking the hackathon including rapid ideation, electronics and coding through trial and error, assembly of multiple electronic components and the transfer of circuits built on breadboards to stripboard.

Rapid prototyping and idea generation/development alongside mechanical development for the steering system. (Participant 26)

I found it really useful to make something that actually has a function using electronics rather than just making LEDs turn on and off, it was also very useful incorporating the electronics into a physical model, having to design around the space available in the car and having wires go through the car. (Participant 27)

Electronics & programming were weak points of mine, being stuck & forced to understand code & electronic pathways has certainly been useful. (Participant 30)

When asked to reflect on what aspects of the hackathon the students found most enjoyable, a number of areas were identified ranging from ideation, rapid prototyping, designing within constraints, applying electronic and programming to a design solution, quick problem solving, amongst others.

I enjoyed the wiring, being able to see my product work and seeing the wheels spin was great, especially combined with the coding for the buttons to allow different types of movement. (Participant 10)

Enjoyed working in a team and rapidly creating a complex CAD model. Short time constraints have allowed for much quicker idea generation and generally a more efficient approach to the process. (Participant 29)

You always felt pushed for time which made the Hackathon more chaotic than other projects like the design sprint. I enjoyed having to design the product and the controller as part of it. (Participant 32)

Student feedback captured a wide range of feedback in relation to the level of preparation, training and support provided (Figure 3). Student feedback captured their perception in relation to product design focused electronics and programming hackathons and how important they felt these types of events related to their future professional practice. Two students identified the hackathon as ‘extremely relevant’, with thirteen stating it was ‘very relevant’, fifteen ‘moderately relevant’ and two ‘slightly relevant’. Students were also asked whether they would be prepared to take part in product design focused electronics and programming hackathons in the future with fourteen students stating that they would be ‘very willing’, ten ‘somewhat willing’, six ‘undecided’ and two ‘somewhat not willing’. Student feedback highlighted that to improve the hackathon experience, they would have liked some benchmarks/targets to achieve by certain times within the forty-eight-hour time-period.

Conversely other students requested that more of the weekly electronics and programming sessions to be tailored more directly to the hackathon activities to help them prepare more effectively. Feedback also suggested that a pre-event launching them into the project would have helped them prepare more effectively for the hackathon. Although the above points are valid, hackathons are supposed to be pressurized challenges set over a short time-period with the hope of navigating, exploring, and producing a solution or outcome that meets the requirements. Providing a pre-launch or providing additional time as requested would go against the ethos of a hackathon and take away the pressures designed to be applied in this setting. This hackathon was an opportunity to encourage students to test, trial and fail in a non-assessed environment, thus promoting opportunities for experimentation, whilst working under pressure without an academic grade being assigned.

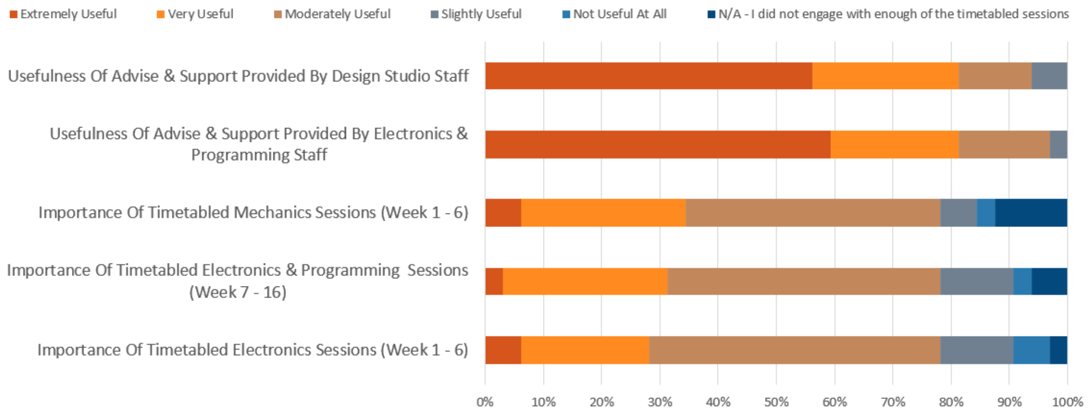

Figure 3. Student response regarding the level of support and preparation linked to the hackathon

Feedback collected also asked students to identify aspects of the hackathon which they found particularly challenging and why. Student responses varied from challenges with teamwork, achieving the task within a pressurized time scale, challenges associated with assembling code together and general electronic issues such as transferring circuits from breadboard to stripboard to produce a more reliable and complete circuit suitable for the obstacle course.

Coding the car was challenging but the support of the tutors was greatly appreciated. (Participant 5)

Teamwork was quite challenging as everyone had different ideas of what to do which made it hard to communicate within a short time. (Participant 28)

Arranging the components on the breadboard as well as transferring it over to the blank stripboard. (Participant 31)

Based on the hackathon experience students were asked to rate the perceived importance of a range of skills and activities used/conducted throughout the hackathon; the results are presented in Figure 4.

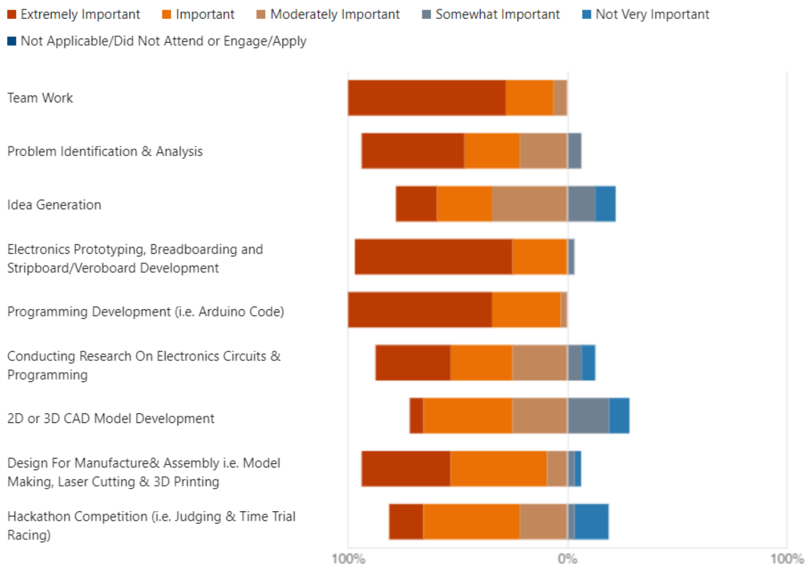

Figure 4. Student response to the perceive importance of hackathon skills/activities

To conclude, the student group rated their overall hackathon experience. Five students stated they were ‘extremely satisfied’ sixteen ‘very satisfied’, ‘ten ‘moderately satisfied’ and one ‘not satisfied at all’. The results suggest that the Hackathon experience had the desired effect by encouraging students to implement their electronics and programming learning into a real-life problem/context, which is often a barrier for students engaging with electronics and programming learning consistently over their studies.

5 CONCLUSIONS & RECOMMENDATIONS

From the feedback collected it was evident that small changes are necessary, in particular, providing further resources to students when preparing for a hackathon. More focus/teaching on translating circuits from breadboards to stripboard is needed as is further time experimenting with motor drivers. No demographic or nationality issues were noted during the deployment or delivery of the electronics teaching block or the hackathon. International students however identified that the recordings of sessions and the supporting captions and handouts helped with any confusion around terminology.

The deployment of the hackathons across the last two academic years has demonstrated how the delivery of an electronics/programming curriculum which is reinforced with a real-life challenge has helped student groups contextualize their learning and put into practice their developed skills. Challenges still do remain with regards to the different speeds for which students understand and grasp the topics of electronics and programming, however the extended teaching block supported by hackathons has without doubt reduced the number of students struggling and failing electronics assessed content.

Based on the implementation of hackathons in the product design curriculum at NTU, and the student feedback received, the following suggestions are made when planning to run/implement hackathons:

1. Provide students with the opportunity to select their own grouping, however, provide clear parameters based on the length and complexity of the hackathon challenge being set.
2. Provide collated kits or standard equipment which all student groups must use as the basis of the hackathon challenge, whilst also ensuring they have access to a plethora of additional resources.
3. Provide clear and designated workspaces for student’s groups both in a design studio environment and within an electronics laboratory environment.
4. Provide clear/explicit guidelines where groups should be at during the hackathon timeline to help keep the student groups focused and on task.
5. Ensure that a diverse staff team is available and engaged within the hackathon environment, in particular ensure that multiple electronics and programming tutors/technicians are on hand to support the event whereby student questions/queries will inevitably be frequent.
6. Ensure student groups do not focus too early on perfecting the design output, rather encourage them to experiment with the electronics and programming as soon as possible to maximize their chances of having functional outputs come the judging/assessment.
7. At the end of the hackathon ensure that all student groups irrespective of the success or failure of the outcome are involved in the review and presentation of the designed outputs produced.

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CRITICAL PEDAGOGIES FOR COLLABORATIVE INNOVATION

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ABSTRACT
As designers of all disciplines are increasingly expected to engage in complex problems, involving social, cultural, technological, and economic issues that reach beyond their own known boundaries, so our students' educational experiences must evolve to better equip them for these challenges. Over recent years our department has embodied this ambition through an integrated delivery of cross-course projects via the Collaborative On-line International Learning (COIL) programme, aiming to support shared learning experiences across diverse cultures. Specifically, this study reports on the delivery of a COIL project between UK and Indian institutions, to foster practices of more inclusive and responsible innovation, engaging students in cultural exchanges beyond their existing lived experiences. Referencing design for sustainability and design for circularity as boundary models, the students worked in mixed teams to explore a design challenge from different cultural standpoints. To evaluate the project's success as a deep learning experience and to measure the extent of the impact upon core design values, the authors recorded student responses to prompt questions regarding (a) their awareness of global issues (b) the students' sense of collective agency within their extended community (c) their confidence in applying methods that extend beyond existing reference points (d) their understanding of complex problems and the connectedness of decision making to broader issues. Results from student feedback and student work were analysed to identify any defined changes in students core design values resulting from their engagement in the projects. The results of this study would be of interest to design academics and practitioners working across global partnerships.

Keywords: Remote collaboration, sustainability, global design, critical pedagogy

1 INTRODUCTION
The imperative for circular design solutions are clear. Driven by necessity to confront the climate emergency, responding to shifting consumer preferences, and the tightening of manufacturing and emissions regulations. Designers of all disciplines, but perhaps those involved in the design of products, are most acutely positioned to inform and influence client decision making around sustainable choices, with as much as "80% of a products environmental footprint being predetermined at the design phase" [1]. However, these are complex problems, involving social, cultural, technological, and economic issues that reach beyond established practices and challenge the predominate linear value chains. The application of circular thinking has never been more important to leverage positive change.

Within the UK, there has been much discussion surrounding the role of design in supporting shifts towards sustainable economy. Slipstreaming the 2021 COP26 (United Nations Climate Change Conference) the UK Design Council, an independent chartered charity, championed design's response in hosting the Design for Planet Festival in November 2021, aiming to support the UK's design industry to commit to a sustainable, climate-first future. Most recently, design practitioners themselves have initiated a national campaign 'Design Declares' offering designers across the design communication, product and service sectors the chance to build a unified voice in the climate emergency, supporting practitioners through a tool kit of actions to deliver change. It is therefore clear that our students' educational experiences must evolve to better equip them for the challenges of a changing design industry. Generating a meaningful response to such global issues will require a diversity of knowledge and skills, with individuals enabled to harness the contribution of distinct disciplinary expertise. Within this Collaborative On-line International Learning (COIL) study, we have begun to explore how to equip students to become designers in a climate-first future, supporting shared on-line learning experiences across diverse cultures to foster practices of more inclusive and responsible innovation by trying to define the tools they will need and how they can use them. Two terms were introduced to the students and used throughout the project, Design for Sustainability and Design for Circularity (circular economy). "Design for sustainability is an approach that puts the well-being of people and the sustainability of the environment first [2]. "Designing for a circular economy has 3 core aims: To eliminate waste and pollution, to circulate products and materials (at their highest value) and to regenerate nature" [3].

2 PROJECT METHODOLOGY

Manchester School of Art, Product Design (MSOA-PD) and MIT Institute of Design (MIT-ID) established an institutional partnership in 2022, supported through the Collaborative On-line International Learning (COIL) programme. In this study, delivered through February - March 2023, MSOA-PD and MIT-ID tutors worked collaboratively to design a project exploring international creative practice, engaging students in cultural exchange along with exploring connectedness, responsibilities and agency as designers via the design of packaging solutions for the Indian and UK markets.

Table 1. COIL partnership 2023 project details

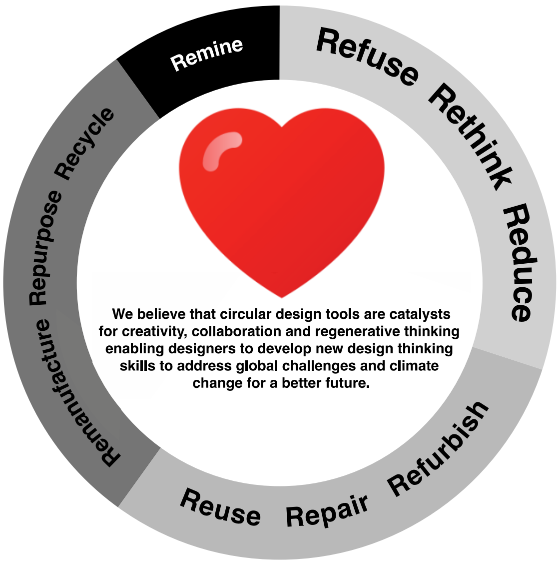
University	Manchester School of Art	MIT Institute of Design
Country, City	United Kingdom, Manchester	India, Pune
Programme	Product Design	Product Design
Course Title	UNIT X	Packaging Design
Learning Outcomes (LO)	LO1: Generate a body of work in response to a given brief, environment, or situation. LO2: Demonstrate the development of personal practice. LO3: Present outcomes and articulate ideas to a peer audience. LO4: Identify skills and attributes for effective collaboration.	LO1: Have an understanding of the Packaging Design Process applied to design opportunities. LO2: Assess and apply all the skills used in a consolidated format. LO3: Ability to come up with a packaging solution fulfilling all the criteria.
Level	Year 1	Year 2
Duration	63 Hours / 1.5 days per week	150 Hours
No. students	20	24

Students were placed in mixed groups from both institutions, meeting weekly via MS Teams, with synchronous and asynchronous collaboration being supported via the Miro on-line platform to enable the sharing of visual work. Throughout the project's delivery, students were asked to reflect upon a series of prompt questions devised by tutors and provided on a weekly worksheet. The questions asked students to reflect upon (a) the students' awareness of global issues (b) the students' sense of collective agency within their extended community (c) their confidence in applying methods that extend beyond existing reference points (d) their understanding of complex problems and the connectedness of decision making to broader issues. Following the project's delivery, all worksheets were gathered and analysed to identify common characteristic themes in responses and the extent to which the cross-cultural engagement and emersion into sustainable design had impacted students' core design practice.

3 PROJECT PLANNING AND DELIVERY

Using the Learning Outcomes as a framework, a curriculum of weekly project outputs required students to follow the UK Design Council's 'Double Diamond model' [4] consisting of four phases: Discover, Define, Develop and Deliver, a model currently used by both MSOA-PD and MIT-ID undergraduate courses. The design brief introduced the students to the packaging categories of Fast-Moving Consumer Goods (FMCG). These products are familiar to both sets of students, purchased regularly (food, drink, self-care, household care, healthcare) and provided a good contextual platform for 'icebreaker' team activities and ongoing discussions about daily routines, cultural similarities and differences.

The project brief required students to re-think an example of packaging considering the needs of the Generation Z (Gen Z) target market, described as being “hyper-aware of how their consumption affects the world around them, obsessed with ethics, sustainability, and inclusivity, they demand that brands focus on these values in genuine ways” [5]. Gen Z provided the trend rationale to focus on sustainability, and broadly matching the demographic of our COIL students (18-24 years old) provided a valid opportunity for our students to discuss how they engage with design for sustainability as consumers.
The on-line collaborative whiteboard platform Miro was utilised as a tool to support collaborative practice in the project. The Miro board presented a uniform set of columns that were used as presentation spaces to share design boards at the weekly review meeting and these boards became the portfolio for submission at the end of the project. A second Miro board was built (Research and Planning) and contained trend forecasting report links about the brief’s chosen demographic and teaching and learning materials used within each programme, including tools to support planet-first designing. In response to the brief, which stated that “the world is currently in the grip of a packaging waste crisis, 90% packaging is single-use and can only be recycled once” [6], each programme delivered teaching about models for climate-first design. The UN Global Sustainability Goals and Design for Circularity (Circular Economy) were introduced using the online Ellen MacArthur Foundation resources [7]. A new model for Design for Circularity, see Figure 1, was also shared with students, developed by Manchester Metropolitan University Sustainability Team. This circularity framework, developed by MSOA-PD team, visually communicates the hierarchy of circular design strategies and formed a guiding set of criteria for students to consider within the design process.



Key to hierarchy of the Circular Design Framework
Refuse + Rethink + Reduce = Actions which support the prevention of materials, or objects becoming waste. This part of the spectrum is actively preventing the impact on the planet and is supporting planetary sustainability.
Refurbish + Repair + Reuse = Actions which result from something falling out of use or being discarded, the result of waste. To become circular, any existing, extant elements, materials and knowledges must remain useful for as long as possible.
Remanufacture + Repurpose + Recycle = Actions which are the result of waste and the inability of a material to maintain useful currency or value to human consumers any longer.
Remine = Action of remining / landfill of a material, contributing to the production of excessive carbon through its disposal.

Figure 1. Circularity framework

The project was supported by packaging industry experts Huhtamaki, an international packaging company who manufacture across the globe to develop sustainable, innovative packaging for global brands including McDonalds, Prêt-a-Manger and Costa and have manufacturing sites in both the UK and India. Huhtamaki provided knowledge into the global packaging industry, offering valuable insights into future visions and participated in the critique of student design work alongside tutors.

4 THE RESULTS

Question 1) Student awareness of global issues:
At the start of the project, both sets of students were asked to upload onto Miro a ‘Hero’ (good) and ‘Villain’ (bad) example of packaging to discuss as an ‘icebreaker’ activity. The task revealed that ‘bad’, or ‘villain’ packaging included examples of excessive packaging, the use of single use plastics in food packaging and non-recyclable packaging in laminated plastics toothpaste packaging. Both sets of students identified similar reasons for categorising the packaging as ‘bad’ even if the brands or products selected were culturally different.

Further information was gathered on Miro from the students about awareness of climate issues, some shared that they had “negative feelings” about them, but all listed several ways to tackle the issues too: “be more aware of recyclable materials” and “stakeholders: businesses and designers being more accountable.”

Question 2) Students’ sense of collective agency within their extended community:

Weekly student meetings created a positive momentum and focus, enabling more ownership of organisation, more time to share ideas further explore the cultural exchanges being made. Student feedback revealed that “consistent feedback was really beneficial” and “designs evolved using collaboration feedback.” Feedback taken at the end of the Unit highlighted that the student teams “enjoyed the experience of working together” and “although our cultures are different, as designers we work in a very similar way.”

The project provided a platform for discussion about the climate emergency, building a sense of collective agency through a shared examination of the evidence of the damage that packaging waste is causing globally. As packaging is also bought and used by the students every day, collective discussions took place in meetings where students could share ideas about alternative, enhanced user journeys that could be imagined within their own shared experiences of buying and using packaging.

Question 3) Confidence in applying methods that extend beyond existing reference points:

Design for sustainability is taught within the MIT-ID curriculum as a formal lecture by a tutor knowledgeable in sustainable materials. Within this project, MIT-ID students focused primarily on packaging innovation, the ‘unboxing’, improving the interactions between user and packaging, with sustainable material selection as a supporting consideration.

At MSOA-PD, design for sustainability is not formally delivered through lectures, instead it is responded to within each brief which involves tutors building their knowledge through networking with MMU colleagues with relevant expertise to support projects. In this project, a new piece of research was developed into a visual framework (figure 1) to support student learning and application of sustainable practice in their designing. MSOA-PD students were introduced to the circularity visual framework through the existing ‘user and product journey’ tool which students use to map out a customer or product journey during its use. Using Rs from the circularity wheel ‘hierarchy’ as a creative catalyst, the user journey was disrupted or enhanced: *rethinking* the user relationship with packaging, *refusing* packaging or *reducing* materials for example. Expanding the user and product journey to visually map the packaging back to the brand or manufacturer provided scope for design routes exploring responsibility and accountability (*refurbishing* or *refilling* packaging for example).

Tutors discussed the approaches to teaching sustainable design throughout the project. Within MIT-ID, knowledge about sustainable materials applied to a design project demonstrates that sustainability has been considered. We discussed however that the selection of ‘correct’ sustainable materials is complex; material sourcing, its carbon footprint or if the material is ‘emerging’ but not yet mainstream for example. It is interesting to note that all of the students shared concerns with not knowing enough about sustainable materials, but unless the designer creates the system in which the packaging is used by the customer, to guide, be incentivised, driven to ‘dispose’ of it in the correctly designed way, the material loses its value (however sustainable the material choice), and the take / make / waste linear cycle continues despite the sustainable material choice at manufacture.

The design project submissions were analysed and revealed that MSOA-PD students all considered and applied a range of circular design principles, in particular Refuse, Rethink and Reduce which on the hierarchy of the Circular Design Wheel are “actions that support the prevention of materials, or objects becoming waste, actively preventing the impact on the planet and supporting planet sustainability” (figure 1). 5 out of 6 MIT-ID teams designed packaging which could be recycled, the penultimate step before Remine (landfill) described as “actions which are as a result of waste and the inability of a material to maintain useful currency or value to human consumers any longer” (figure 1) with the remaining team focusing on refilling the packaging after use.

Question 4) Their understanding of complex problems and the connectedness of decision making to broader issues:

MSOA-PD students shared that “MIT-ID did want to work in a more sustainable way, but the function of the product was prioritised” and it was noted by MIT-ID students that MSOA-PD ideas were “more liberal with experience prioritised.” This feedback evidences the different approaches and priorities within the curriculums. This feedback also captures the importance of universities sharing practice through projects like COIL, working together to develop the tools to use in understanding complex problems. As reflected in MIT-ID's mission and vision: "MIT-ID aspires to nurture a *design education ecosystem* to develop future ready professionals with planet centric perspective using cutting edge technology and to promote the craft of design for a better life on planet earth" [8].

5 CONCLUSIONS

This project engaged students in using design as a creative tool to respond to a global issue. Working collaboratively with international partners (as peers) attempted to heighten their sense of collective agency and build responses to issues through design driven approaches that look beyond localised frames of reference.

Results from the project and analysis of student feedback revealed that:

(1) Using circularity as a set of design prompts to enhance existing design research methods can potentially lead to a wider scope of ideas for sustainable design. This was particularly highlighted by the use of the circularity framework, by providing students with a visual hierarchy that indexed sustainable strategies enabled a clearer evaluation of desirable versus less desirable choices to be discussed and understood.

(2) Students have developed an awareness of sustainability beyond a focus on material choice within a sustainable design decision making process. Understanding human behaviour, designing in and retaining material value with systems that support sustainable decision making throughout a product's lifecycle are also critical considerations that previously lacked recognition.

(3) Project results and student feedback suggests that the use of journey mapping as a collaborative design method to create a shared boundary object can equip students to explore and challenge the complex journeys of packaging *including* sustainable material choices and the complex set of decisions that customers make. By mapping these journeys and visualising the relationships between the brand, packaging and user, multiple circular design interventions can be made, generating meaningful alternatives in this way proved useful in expanding both sets of students' confidence to apply design ideas beyond their own local reference points.

In summary, the project's combined use of consumer centred journey mapping and visual framework for circular strategies has been successful in supporting a greater understanding of systemic thinking, and the considerations for decision making. Students more clearly recognise the need to look beyond material choice and user functionality. In responding to a design issue collaboratively and across cultural boundaries many of the students appear to have gained a greater holistic sense of their own responsibilities and agency as designers within a global context. We believe that establishing these benchmarks early in design education is significant in fostering a sense of collective agency amongst students to inform a positive sustainable future for design practice. As our students become the next generation of graduates their role in ensuring accountability of business, government and guiding better consumer decisions that embrace sustainability is imperative.

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IMPROVEMENT OF THE LEARNING EXPERIENCE IN ENGINEERING COURSES THROUGH THREE SUCCESSFUL CASES OF IMPLEMENTATION OF EMERGING TECHNOLOGIES IN THE CLASSROOM

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ABSTRACT
The teaching-learning process has become, along with technological advancement, a dynamic process that adapts to the circumstances of the challenges that arise in the teaching-learning process, added to unpredictable environments for its development, have led the teachers to develop innovative ways of teaching inside and outside the classroom, as well as with flexible digital models that allow distance education. Whatever the innovation, it must enable the student to have a great experience in their learning process and meaningful learning. Given these circumstances, using technologies that help and facilitate students' learning paths has become more recurrent and essential. Technologies that, complemented with didactic techniques such as gamification, efficiently affect the teaching process, making it more productive in terms of the use of resources and the achievement of objectives such as skill development. This study presents an in-depth analysis of three successful cases of educational technology implementation within the teaching model of our university, which focuses on the student and favours the development of competencies. The applied technologies were: Virtual Reality, Simulation, and Telepresence. Once these technologies have been validated, their adoption is highly recommended to use them for the benefit of education at different levels and areas. The article results from different NOVUS projects, innovation for education, carried out at the Tecnologico de Monterrey, with proven successful results.

Keywords: Virtual reality, simulation, telepresence, technologies, education

1 INTRODUCTION
The challenge of any teacher in the classroom is to design better ways of learning, this is called educational innovation. Looking for students to maintain attention, have learning and develop skills generates motivation and creativity in the teacher. In the context of the teaching-learning process, the aim is to achieve the greatest impact in the development of knowledge and skills in the students, which is why the best didactic tools are sought for their use and implementation in the classroom, always seeking innovation. Technology in the classroom is an excellent tool to generate learning and develop skill, it can be used within gamification to generate more interest in students. Three trends in Education 4.0 related to educational innovation to be addressed are (i) students deciding the best method for learning, (ii) innovations in current learning tools, and (iii) use of digital tools and emerging ICTs (López et al., 2021).

The following paper summarizes three initiatives financed by the Institute for the Future of Education of the Tecnologico de Monterrey that have successfully developed transversal and disciplinary competencies of students in the School of Engineering and Sciences. MxREP, or Chencho Project, is an EPR simulator with virtual and augmented reality lessons. The design of an Interactive Virtual Environment for the training of operators is focused on developing skills in students through the total immersion that virtual reality gives and, finally, the Avatar Professor that allows the experience of having the best teacher in your classroom regardless of the distance. The professors of the Tecnologico de Monterrey seeking to carry out the best practices of the teaching-learning process have given themselves the task of using different technologies for the benefit of education, technologies such as virtual reality, simulation, augmented reality and telepresence. Each of these technologies have given positive results for student learning.

2 METHODOLOGIES

2.1 Case Study: Chencho Project, an ERP Simulator with AR and VR activities

Chencho is an ERP simulator for learning industrial engineering concepts such as; Quality Control, Logistics, Design of Experiments, Production Planning, Project Management among others and is based on a gamification platform. This simulator was a response to the distance learning needs motivated by the confinement by Covid-19; it is based on manufacturing Meccano cars and is supported by virtual and augmented reality lessons. The first design was based on an SAP model, introduced in August 2020 during distance learning. It was based on solving a case (Figure 1). The first experimental run was carried out in the field of Problem-Solving Methodologies at the national level and online, with a group of 361 students in each of the 26 campuses of the Tecnologico de Monterrey. The first augmented reality lessons were made based on the traction system of a Formula 1 model, and the main case was based on a problem of tolerance sums in gear systems. Based on the learning activity design model proposed by González et al. (2021), through the design of experiments and design thinking, the environment was changed from similar to SAP screens to a gamification based on a robot, customized by the student. It competed with other robots to do the best manufacturing process, fulfilling all work orders and maximizing profits.

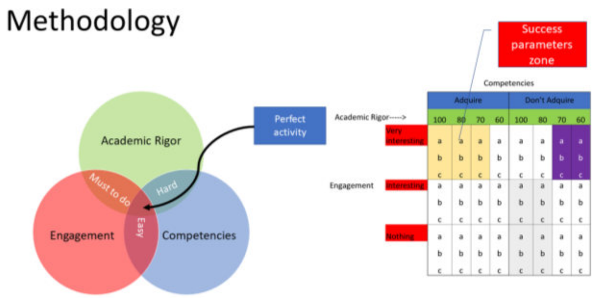

Figure 1. Methodology of the modification of the Chencho project

2.2 Case Study: Design of an Interactive Virtual Environment for the training of operators

The methodology of this research was of 2 phases: 1) The students were presented with a virtual environment in which they solved the expressed need of the problem, they had a week to develop it; furthermore, its objective was to analyse the skills developed of the students from the perspective of the solution presented through the 3D interactive virtual environment (Figure 2). Additionally, the first analysis was intended for students to be able to recognize the set of competencies they had developed and had a starting point for, once the presentation was made, to define the level of development of said competencies González et al. (2021). 2) The students were asked to answer a questionnaire about the skills developed and the level of said development, this work presents a qualitative analysis of how a sample of 37 students recognize the development of four competencies according to these levels, these levels vary from a basic level of a competency to a high level reached. To achieve this, all the students who took the project were asked to evaluate the level of development of the skills already described that they acknowledged having achieved during the project. The evaluation levels of each of the questions were: *Basic*, *Medium*, *High* and *Null*.

Figure 2. Demonstration of the use of the virtual environment

2.3 Case Study: AVATAR Professor

In 2017, a team of developers investigated evidence in publications where telepresence resulted in a different experience, furthermore, Tecnologico de Monterrey has distinguished itself by promoting educational innovation while facing the challenges of a multi-campus educational system (25 campuses). The holographic courses have been implemented on 11 campuses, two of them capable of transmitting and receiving, and nine receiving centres. The developers found that telepresence with a hologram made the students feel closer to the teacher more significantly than traditional videoconferences. With the hologram effect, the students saw their teacher in the anatomically correct size and could interact with him or her in real time, thus achieving telepresence. Pelet et al. (2017) described this phenomenon as a perceptual illusion of being present without feeling mediated by technology. This feeling can also be achieved with other media and contexts. However, the students reported feeling focused and immersed in the experience. This sensation is described in the literature as the state of flow. Flow is a psychological state characterized by an intrinsically pleasant, optimized experience. To recreate a face-to-face educational environment in distance learning lacking the physical presence of the professor, the developers created the Technological Ecosystem for the Telepresence with Hologram Effect Model (Figure 3).

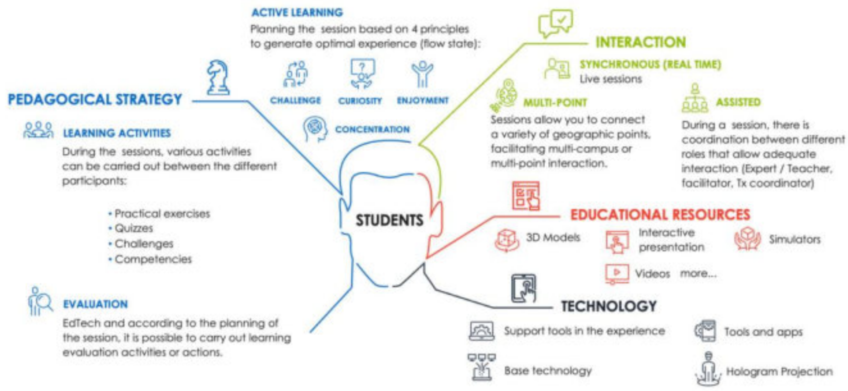

Figure 3. Technological Ecosystem for the Telepresence with Hologram Effect Model [5]

To understand and analyse the participants' perceptions, feelings, and opinions, Strauss and Corbin's representation was used, with the objective of linking empirical data with theory, in addition to Grounded Theory design (GT), which was a tool to analyse and understand the obtained data. The total population was 567 students from different campuses throughout México; this innovation encompasses seven courses, from which three were of Engineering, three of Business, and one Architecture. The study

took place during the semester of August-December of 2019. The students had an age range between 17 and 20 years, as such they were at different stages of their professional careers.
Moreover, an instrument was designed to collect data based on the research questions: 1) *How do students in telepresence-with-hologram courses evaluate the educational experience?* 2) *What characteristics of telepresence-with-hologram courses are meaningful to students?* It's worth mentioning that the questionnaire followed Glaser's guidelines for an open-question instrument prompting.

3 RESULTS

3.1 Case Study: Chencho Project, an ERP Simulator with AR and VR activities

The learning development for the students was good. However, the stress caused in the distance simulation, the interpretation of results, and preparing the case solution report represented a high stress for the students under the context of distance learning in total confinement in their houses.
The results obtained by this gamification in the classroom were surprising in the three study variables, *improvement of academic performance*, *student engagement*, and *development of skills*, and the results improved when virtual and augmented reality lessons were incorporated in which students they could analyse the MRP of materials of each product as well as quality problems by exploring the assemblies themselves without the need to assemble the Meccano physically. Figure 4.
Gamification by itself has significant benefits in education, such as a sense of competitiveness that makes the student addicted to the game and seek learning to improve their performance. This learning is to implement the industrial engineering techniques seen in class. During the simulation, it was observed that the students developed disciplinary learning and could simulate it until they found those parameters that maximize profits. The final reflections in the essay that summarized the experience of the simulator show the development of skills such as teamwork, the reasoning for complexity, and problem-solving.

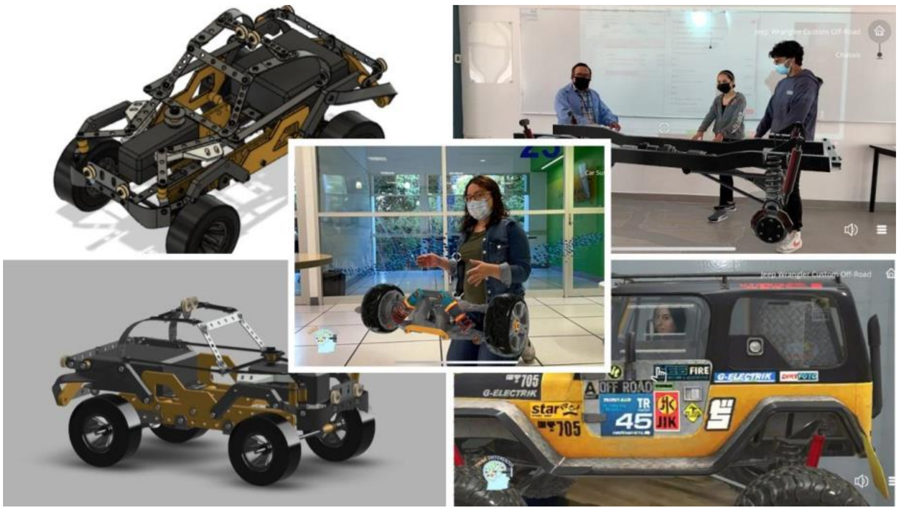

Figure 4. Checho gamification

3.2 Case Study: Design of an Interactive Virtual Environment for the training of operators

Below the analysis of the results of the answers to each of the questions asked is presented:

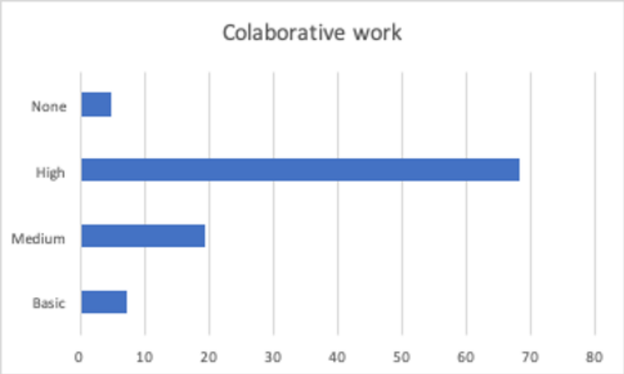

Figure 5. Analysis of the collaborative work competence

Figure 5 shows the results of the question, *What level of development of the collaborative work competence do you think you have reached as a result of your participation in this challenge?*, can be seen that a large majority of the students stated that they recognize a high development of the collaborative work competence, this means that the students recognize that the competence is fully developed and that they feel safe to demonstrate their knowledge and skills. Putting this competence into practice for the benefit of a problematic situation (González-Mendívil, Rodríguez-Paz, & Zamora-Hernández, 2022). Along with this, it is very important to point out that a little more than 80% of the student's state that they have a medium-high level.

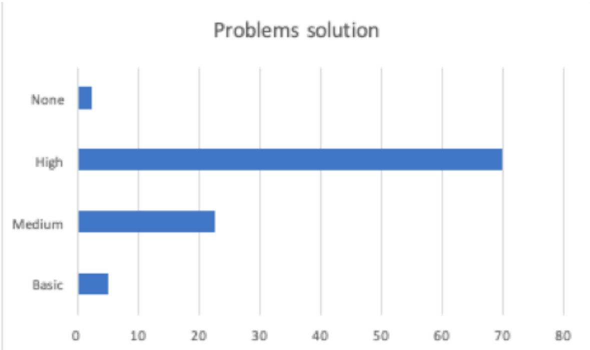

Figure 6. Analysis of the problem-solving competence

Figure 6, on the other hand, shows the question: What *level of development of the problem solving competence do you think you have reached as a result of your participation in this challenge?* and as in the previous case, most of the student's state that they feel that their competence is fully developed, since they are recognizing a high level of development of problem-solving competence.

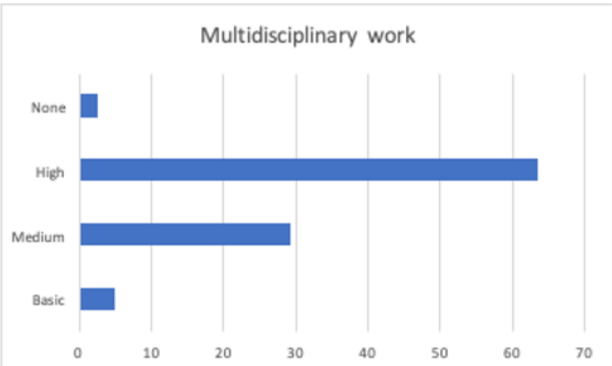

Figure 7. Analysis of the contribution of multidisciplinary work

Figure 7, presents the question *What level of contribution did the multidisciplinary work have to achieve the result of this project?*, in this analysis evidence is presented that most of the students consider that

the multidisciplinary work had a medium to high contribution to achieve the objective of the project with almost 93% evaluation.
In general, the results indicate that students recognize a high level of development of these competences, and this shows that this type of activity is an important approach to help not only students but also people in general to ensure that they have reached a certain level. level of competition (Rodriguez-Paz, González-Mendívil, Zamora-Hernández, & Sanchez, 2021).

3.3 Case Study: AVATAR Professor

Overall, in the telepresence courses the students have the opportunity to identify what excites them and appreciate the dynamic nature of the class, in addition to feeling comfort and amazement to the innovative tool that was developed. The educational experience of the telepresence courses with technological infrastructure gives the students a combined sense of innovation and comfort when seeing their teacher's life-size image, while providing an unique aspect of interaction from student of different campuses; on the other hand, for the professors it provides an opportunity for creating better learning conditions and interactions (Ramirez-Lopez, Castano, Aldape, & Tejeda, 2021).

4 CONCLUSIONS

In conclusion, the support of technological tools in a gamification process helps the students achieve more meaningful knowledge; it improves the collaborative work between students and is encouraged by using technology in learning. Moreover, it motivates students to learn as technology can make the learning process more attractive, as there is a flexible teaching process because of easy access to technological tools at a distance.

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RESEARCH ON SUPPORT METHODS FOR HIGH SCHOOL TEACHERS EDUCATING SDGS WHILE UTILIZING DESIGN METHODS

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ABSTRACT
As society slowly moulds the planet into a sustainable world in response to natural disasters and social injustices, human resources must be fashioned to meet the new challenges that such a future requires. The Sustainable Development Goals (SDGs) are obstacles that nations strive to achieve, and it is necessary to teach younger citizens how to accomplish them. This study approaches this type of education in a novel manner by applying design thinking. An SDGs Challenge project took place in a high school with support from a university to identify problems in SDGs education, devise a strategic support plan to carry out this specialized education, and observe the effects of such an implementation all while using a design approach. It was found that there are specific issues that arise in inquiry-based learning that must also be addressed in a unique way. The support system created through the project showed instructing educators to utilize design thinking improved their abilities to teach students, and also improved students' output in identifying and solving SDGs related problems. The results show how much of an impact the design methodology can have on education and the positive implications for applying such teaching support methods in high schools worldwide.

Keywords: Design thinking, SDGs education, teaching support

1 INTRODUCTION
In order to respond to rapid changes in society and the economy, it is necessary to develop human resources who understand the SDGs [1], can proactively propose solutions, and obtain skills based on conventional knowledge-oriented education. To meet this "zest for life" required by society, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) announced in their 2018 revised Courses of Study for High School, that the new "Period for Inquiry-Based Cross-Disciplinary Study" will be implemented in high schools by 2022 [2]. Hence, students need to develop the qualities and abilities to better identify and solve problems while considering their own way of being and living through independent, interactive, and deep learning.
Currently the "Survey on High School Education Reform 2021" report conducted by Recruit College Preparatory Research Institute states that 93% of high schools in Japan have already introduced the "Period for Inquiry-Based Cross-Disciplinary Study"[3]. However, those in charge of the programme are deeply troubled in the face of the high demanding standards of "inquiry" [4]. It was suggested that in implementing inquiry-based learning with the SDGs, it is necessary to develop the environment, such as appropriate assessment methods, effective teacher assignments and time for activities, and to provide information on how to promote inquiry activities, to name a few of the concerns [5]. There is an urgent need for teachers to know how to support students in learning about the SDGs as the world moves towards global sustainability.

2 PURPOSE
The aim of this study is to propose a support method that will help teachers to solve the challenges they face in SDGs education for high school students by utilizing design thinking.

In 2021, Kyushu University, in partnership with Fukuoka Municipal Fukusho High School, conducted a study on SDGs education by implementing an "inquiry-based cross-disciplinary learning period" for high school seniors. Special attention was given to the problem-finding stage of this process and the difficulties faced by teachers placed to be charge of this education programme were articulated. The findings from this case study are the basis of the support proposal.

3 RESEARCH METHODOLOGY

3.1 From the results of 2021 research

The SDGs Challenge Project of Japan Fukusho High School conducted in 2021 was used as a case study. A total of 27 high school teachers from various fields such as language, social studies, and art were instructed on SDGs education for third-year high school students. Teachers were given a questionnaire survey inquiring about difficulties in identifying social issues in this context and 314 students completed a feedback questionnaire survey.

The data collected showed most of the instructors reflected with respect to (the difficulty of) understanding the educational process and the incorporation of design thinking, particularly in the problem-finding stage. From the findings, it is very clear the difficulties rely not only on the problem definition alone, but rather on the procedural aspects of the facilitation process itself [6].

The second type of challenge that many instructors responded was to the facilitation of the group work; groups working at different speeds, lack of motivation, and poor communication between students in the group was evident.

3.2 Pre-questionnaire before the SDG education programme in 2022

Because teachers in charge of SDG education programmes in high schools may change every year, it was necessary to conduct a preliminary survey to find out how much design understanding teachers in charge have. In 2022, 27 teachers assigned to this programme from different disciplines such as math, social studies and physical education were asked in advance about their educational experience in design, their understanding of design thinking, and their confidence in facilitating group work. The results of the survey include answers from 24 of the 27 teachers. Only one of the 24 teachers had teaching experience in design. It was found that this teacher had an understanding of design thinking, while the other teachers had little or no understanding. Regarding their confidence in teaching group work, 18% of the teachers were found to be a little confident, while the others were not so confident.

The results of the above two surveys were summarized and suggestions for support methods were collected to ensure that the 2022 SDG education programme would proceed smoothly.

4 PROPOSALS FOR SUPPORT METHOD

In response to the findings, it was found that support is needed for teachers' lack of understanding of design thinking and their lack of confidence in facilitating active teamwork activities. Addressing this issue directly by helping teachers solely at this stage cannot solve the overall problem. In order to be able to better support the students, an overall support structure is needed that is tailored to the educational process. Specifically, together with an education officer and an education supporter, a proposal for a support structure that includes who, when and how to support (Figure 1) was made. Apart from the education project actors Fukusho High School and Kyushu University, this support approach is also intended to incorporate other parties to fulfil the role of third-party evaluators. The idea is also to be able to support a high school in its entirety before, during, and after the educational programme in line with the educational curriculum of the high school.

Figure 1 displays the three stages of support proposed: a) before the programme, b) during the programme, and c) after the programme. The roles of the support system of Fukusho High School, Kyushu University and external supporters were identified. Fukusho High School will carry out educational activities. Kyushu University will utilize design thinking and provide overall support for educational activities. The external supporter will provide comments on the students' presentations.

Regarding the lack of understanding of the educational process incorporating design thinking, especially the difficulty of problem identification and facilitation of group work, the most effective method found to solve such difficulties in a short period of time is a workshop for teachers. Teachers are put in the same position as students; they experience the process of problem identification and problem solving and formulate their own solutions as to how to proceed with the class. Workshops for teachers require both pre and post-workshops. These two workshops are conducted by teachers from Fukusho High School and Kyushu University together; A3 is a pre-workshop for teachers to understand design thinking, the SDG education process, and specific methods. This workshop can also be described as a mock class. C3 is a workshop after the end of the education programme, which is useful for evaluating the programme as a whole and organizing areas for improvement.

Figure 1. Support method for SDGs education

5 VERIFICATIONS

Questionnaire surveys and interviews of the teachers in charge of the programme were conducted after the classes. In addition, a questionnaire survey of 301 students who participated in this education programme was conducted to verify whether this support method was effective.

After the SDG education programme, the same questionnaire was given to teachers (17 teachers in 2021, 24 in 2022) who participated in the study. Figure 2 shows how responses compared between the years regarding educational outcomes.

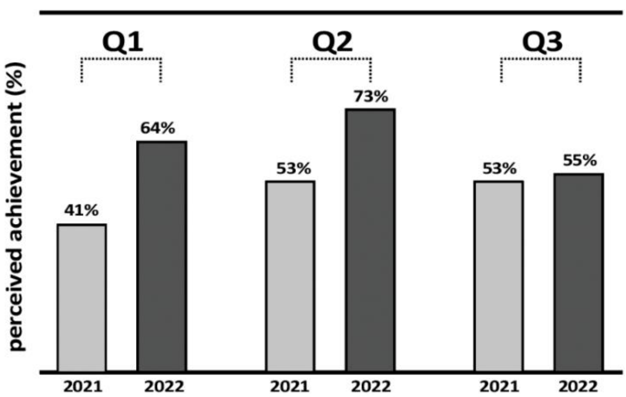

Figure 2. Post-questionnaire responses 2021 and 2022 after SDGs education training

Question 1 asked: How much do you think you have achieved in terms of “knowledge and skills?” Forty one percent of the teachers in 2021 responded *very good* and *good*. For the 22 teachers in charge in 2022, 64% responded *very good* and *good*. Question 2 asked: How much do you think you have achieved in terms of “thinking, judgement, and expression skills?” In 2021, 53% responded *very good* and *good*. In 2022, 73% of teachers perceived their achievements as *very good* to *excellent*. Question 3 asked: How much do you think you have achieved in terms of “ability to learn and exemplify human nature?” For the 2021, 53% responded *very good* and *good*. While for teachers in 2022, 55% responded *very good* and *good*.

The above results show that the perceived educational outcomes of the teachers in charge in 2022 were higher than in 2021. In particular, the improvement in educational outcomes was found to be greater with regard to “knowledge and skills” and “ability to think, judge and express.” The SDGs education training appears to have improved the understanding of design thinking of the 2022 teachers from 2021 and thus is reflected in their responses. Learning is conducted in stages, and it is easy to see the effect in terms of acquiring knowledge and skills first.

However, the application of design thinking appears to be is ineffective in developing the “ability to think, judge and express.” This may be due to the idea that in contrast, human nature is based on complex content, so no significant results were seen this time.

6 CONCLUSIONS

Based on the validation results, the proposed support method (Figure 1) is considered to be effective. There are three important points in this support method.

1. This support method involves the participation of SDG education programmes and design specialists as supporters in addition to the educational cooperation partners Fukusho High School and Kyushu University. Involving outside parties in the interim and final presentations for the purpose of providing objective comments and advice on the students' proposals will have a positive impact on the teaching methods of the teachers in charge of the students.
2. A support system for the entire educational process before, during, and after the programme was created. It is very important to see in advance how the design thinking process will unfold in educational activities and to understand why such a methodology is necessary. It is also important to provide overall support so that after the class, educators can look back, clarify what is good and what needs to be improved, and create a good cycle that can be applied to the next class.
3. From a co-design perspective, Fukusho High School, Kyushu University, and outside supporters will cooperate to create a support system that facilitates teachers to conduct classes, so that even with various educational specialties and experiences, all teachers will be involved to ensure that the SDGs education programme proceeds smoothly. It is important to create a system that allows teachers to create tools according to their own needs in accordance with the educational process, practice them in class, and further improve them, whilst using the design method to create educational tools. A number of previous studies on SDG education methods and educational tools for high school students have discussed the importance of educational tools [7] [8].

In addition to the support structure diagram in Figure 1, the development of support tools according to the educational process was found to be very important in order to be able to better aid the students. We tried to create a support structure with educational tools as shown in Figure 3.

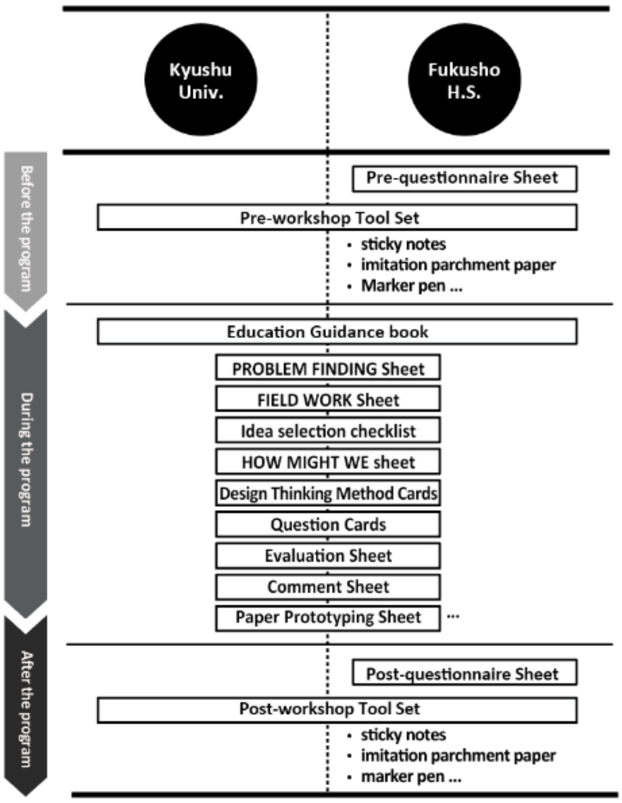

Figure 3. Support tools of SDGs education programme

Future research can be further developed with teachers on the SDGs education programme with the cooperation of Kyushu University and Fukusho High School, with a view to specific development methods for educational tools.

This research is aimed at high school educators in diverse areas working on social issues. As education on social issues such as the SDGs is promoted in the future, this study is significant because it contributes to the development of human resources who can proactively propose solutions by solving the issues identified by this study. This study proposes a creative method that creates a nexus between “design thinking” and the SDGs. In addition, the results can aid society by, for example, creating educational materials based on this support proposal to be available online freely, which can be used in other educational settings.

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LESSONS LEARNED: FURTHER STRATEGIES FOR THE IMPLEMENTATION OF E-PORTFOLIOS IN ENGINEERING SCIENCES

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ABSTRACT
In spring 2022, we implemented e-portfolios at a product design course for engineers in the bachelor's programme on 'Sustainable Engineering' at the University of Applies Sciences, Ansbach. The use of e-portfolios was new to both students and lecturers. To evaluate the effect the e-portfolio had on students, we accompanied the implementation with surveys and interviews. This paper provides a comprehensive analysis of the evaluated results. Among other things, the following three main findings convinced us to continue with e-portfolio work. First, ~91% of the interviewed students felt that they were supported very well by our introduction. Second, ~93% got along well / very well with the functions of the e-portfolio software. Third, ~86% of those interviewed appreciated the freedom of design. Prior to the implementation of e-portfolios in our first test course, we identified the following factors as crucial for the successful implementation of e-portfolios: a comprehensive personal introduction, extensive information material, continuous guidance, clear work instructions, room for flexibility and creativity to foster learners' individual strengths, and exchange between learners and teachers. This paper reflects on these initial factors. The aspects identified for further improvement in the second round of e-portfolios, in the summer of 2023, are better technical preparation of the lecturers, the communication of technical borders in advance, timing of the accompanying e-portfolio workshops and a more comprehensive promotion of teamwork. The suggested modifications will be discussed in detail in this paper.

Keywords: E-Portfolio, design, student feedback, didactic strategies, teamwork

1 INTRODUCTION
E-portfolios are rarely found at German universities, although they offer a lot of benefits to lecturers and students [1]. We want to change this and share our didactic experiences in the field of engineering with other universities. So far, field research into didactic strategies of e-portfolio implementation in the German speaking area mainly comes from the fields of teacher training and foreign language teaching [2-4]. From the perspective of the discipline of engineering, we want to offer new contributions to this topic. In the spring of 2022, we implemented e-portfolios (using Mahara software) in a course on project-based product design from a bachelor's degree programme for 'Sustainable Engineering'. It is the only course focusing on product design in the curriculum of the bachelor programme. The students faced a challenge to *design* and *build a* wooden product for children [5]. At the beginning, one lecturer taught the theoretical aspects that provided the content for the relevant project management and product design (90 minutes per week over the first four weeks and three other lectures that the students had to carry out on their own via digital material). The practical part took place in a laboratory and was accompanied by the lecturer and a laboratory engineer (90 minutes per week, for 14 weeks). Previously, students had to demonstrate the skills that they gained through a seminar paper [6]. This form of examination did not really reflect the creativity and complexity of the project. Therefore, we decided to use e-portfolios as a more diverse tool. Students can document what they have learned more easily via pictures, videos, embedded links, and text (nice design). In March 2022, we implemented e-portfolios as a tool for the documentation, reflection, presentation, and proof of the acquired skills. The students learned to use the software in eight weekly workshops (for one hour a week, see Figure 1 below).

Before implementation, we identified the following four important aspects that should be considered in the development of didactic strategies (based on the literature and our own field research findings). First, a comprehensive introduction to e-portfolios because they are an unknown tool for most of the students; second, a clear, well-defined framework and guidelines; third, weekly tutorials as part of a compulsory course; and fourth, mutual exchange, feedback, and teamwork, as important parts of autonomous learning [5]. We want to show how the general acceptance of e-portfolios was achieved and how our students assessed the different aspects which we identified as being important. The aim was to also indicate which findings were expected, which surprised us and what changes can be planned for the next round of testing.

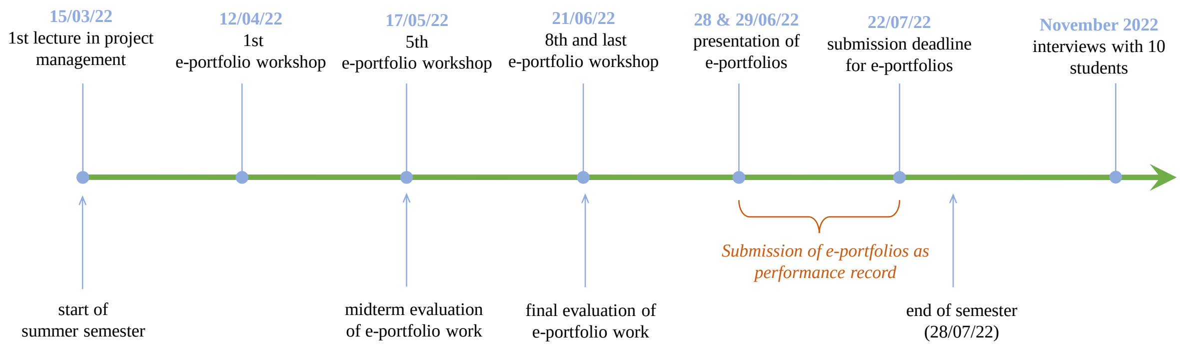

Figure 1. Time overview test course 1 (summer semester 2022)

2 IMPLEMENTATION RESULTS

We received a lot of e-portfolios that fully achieved the required tasks and were very well done. At the middle and the end of the course phase, the students answered online questionnaires (a mix of open and multiple-choice questions), in which they were asked about their perception of e-portfolio work. Evaluation topics were the general acceptance of e-portfolios, the added value that students see in portfolio work, the obstacles for e-portfolio work, and the assessment of our introductory workshops and information material. After the course, we also conducted expert interviews with 10 students from the test course (16 participants in total). The paper brings together the results of our different evaluations and shows how the factors that were identified for a successful implementation of e-portfolios were evaluated by the students and what changes we suggest for our second test course in the summer semester of 2023.

2.1 The general acceptance of e-portfolios

In the first online questionnaire, 14 students answered questions about their impressions so far. For 93% of them, e-portfolios had been an unknown tool before the start of the course. 67% of the students felt motivated to try e-portfolios, 33% were more sceptical about them and questioned the effort of learning a new tool, asking why they would ever need it again.

In the 8th workshop, 11 students filled out a longer digital survey. This time, 36% gave quite sceptical answers regarding their lasting impressions of Mahara, mainly criticising the usability of the software. 64% of the students described the use of the software as being positive and only 50% could imagine using Mahara e-portfolios again, in other courses. At this time, many students had not completed their final portfolio and the exam phase was imminent.

After the course, which was also after the exam phase, we conducted expert interviews with 10 students from the test course, using a semi-structured questionnaire. This time, the answers referring to the general acceptance of e-portfolios, were strongly divergent from the answers given in the questionnaires during the course phase. Nine of the ten interviewees said that e-portfolios would be their preferred examination form and all ten found that they had much more fun with this performance record than with term papers or exams: ‘Yes, in any case, one has been able to realise oneself.’ At the same time, they felt positively challenged: ‘It went much better with me (...) but it was still demanding, you still had to do something for it.’

Furthermore, they felt less pressure because they could work continuously on their portfolio and did not need to know everything at a certain time: ‘I think it's good to get away from the bulimic learning because we were able to finish our project step by step.’

In conclusion, it can be said that the students had a very high acceptance of e-portfolios as new performance records. This is especially true at the end, when the students reflected on their e-portfolio work, in direct comparison to the exams they had passed.

2.2 Barriers

Before the course started, our plan was to identify a top ten of barriers to e-portfolio work at the end of the test round. However, in the concluding interviews the students either named none or a maximum of three barriers: ‘Actually nothing has inhibited me, to be honest.’ This shows that, with the help of our didactic strategies, we can already prevent a lot of potential problems that can occur with the introduction of a new digital tool [7].

The only factors that some of the interviewees perceived as barriers were (i) the usability of the e-portfolio software (70%), (ii) the great deal of effort required to come to terms with a new tool (20%), (iii) the fear of the new (20%), and (iv) the fear of having to be creative (10%).

(i) The main criticism of the software was that some functions were not complex or intuitive enough, like a timetable on Mahara, where it was not possible to backdate past events. At the beginning, they also had problems with the uploading of data because the pre-set memory space was too small. It should not have been a problem to increase the storage space but we, the lecturers, were also newcomers to Mahara and had not recognised or solved these points before the students. With respect to other little challenges, where we had anticipated possible pitfalls, the students stayed quite relaxed. After having found alternatives for the first technical problems, the students were more positive about the software: ‘Yes, in the beginning, it didn't go so smoothly. But then you managed it relatively quickly and well.’

This shows that it is very important for the lecturers to know the software very well and can point out the limits of Mahara in advance, to avoid expectations that cannot be fulfilled later.

(ii) The effort to get to know a new tool was only criticised by two students. In the end, both of them found it interesting to have worked with an e-portfolio: ‘In conclusion, this is a cool gimmick that you have learned there, I've just never done such web pages, so it was great to do something like that.’ One of the two would always prefer an exam to e-portfolio work as a performance record.

(iii) The scepticism towards the unknown, as a barrier, was also mentioned by two students. Both changed their mind later. One of them evaluated the portfolio work very positively in the end and noted that his attitude towards new things had changed: ‘Yes, you just shouldn't jump to conclusions and take a look at it already.’

(iv) One of the students had also mentioned his fear of having to do something very creative or ‘artistic’. This was his interpretation of our arguments for e-portfolio work when we introduced the portfolio as a more creative tool for documentation. To avoid this misunderstanding in the next test round we should, rather, use the phrase ‘freedom of design’ to explain what we want to offer with an e-portfolio. This should prevent students from thinking that they have to produce a piece of art.

2.3 Added values of e-portfolio work

What the students really appreciated about e-portfolio work was the clear structure of an e-portfolio collection and the fact that they received an overview of their project results. Page after page can be added and the collection can be flipped through digitally, just like a real book. In the survey, during the course phase, 50% of the interviewees named this point as positive. In the interviews after the course, 44% of those interviewed positively mentioned this aspect again: ‘That you see your collection growing. I thought that was really cool to see. And that also motivates you to continue and finish your collection.’

Other added values of e-portfolio work which are very often named, are the variety and freedom of design (43% in the survey and 67% in the interview): ‘I think it's cool that you can just bring in so many different things - videos, links, images, text. It's cool that it's all so jumbled up and you don't just rattle off text.’

Comparisons with a classic seminar paper were mentioned as being very motivating (14% in the survey, 33% in the interview). Some based their preference on a lower workload, whereas others found that the workload was roughly equal. They preferred the e-portfolio because it offered more variety and fun than the seminar paper: ‘Otherwise, you always think, no, I don't want to study and it's easier to get distracted. But when I was in this e-portfolio, I just concentrated on that, and I thought that was good.’

In the interviews, 22% also referred to the flexibility of the application. First of all, you can work on the portfolio from anywhere, which is motivation to edit your portfolio more often and this led to people working continuously with it. Secondly, the e-portfolio can be more than one thing, meaning that it can be used as a documentation book but, also, to present the project, when you fold in the text and just show the headlines and pictures.

2.4 Offer of support (comprehensive introduction and information material)

Since Mahara was completely new software for all students, we offered them a comprehensive introduction via eight accompanying workshops during the course phase, where they learned to use Mahara step-by-step and to continuously work with it during the semester. As shown in Figure 1 we only started with the workshops after the first four lectures. This was due to technical issues (we got the access to the software later than expected) and not part of our initial didactic strategies. We would recommend introducing Mahara before or in parallel to the first lectures.

The overall feedback to our introductory workshops and information material, anyway, was very positive. All students felt well or very well supported (according to the survey results). Also, in the interviews, the students evaluated the offer of support to be very positive: ‘That we have gone through it all together with you, that was definitely very good.’

The success of our support was also decided by the e-portfolio template with work instructions, which was provided to the students: ‘It helped a lot to get a rough overview. So, I think without the example presentation it would have been much more difficult.’ All 10 of those interviewed found the template to be very important and supporting because it gave them a clearer idea of our expectations. They simultaneously felt that they had a lot of freedom of design, as our guidelines gave the students the freedom to decide how to document their results themselves: ‘Because, nevertheless, it still became clear that everyone can live out as he wants, can design as he wants.’ This matches our assumptions, based on the interviews with other lecturers and former students, as well as the findings from other researchers, who discovered the demand for a clear structure and the wish for liberty and creativity as being essential [3]. For this reason, we will definitely maintain our template and work instructions.

Only the volume and number of workshops could be reduced (from 8 to 6) for the majority of those interviewed. They would prefer a more condensed introduction, with fewer but longer workshops (90 minutes each). On average, the students think that a total of 6 hours seems appropriate. For some, it was more a question of time saving and their semester timetable (they had to come to university for only one hour, because they had no other courses that day). Others prefer a condensed introduction because they want to get to know all of the elementary functions from the beginning and then work with them independently. The students positively mentioned the fact that they were motivated to continuously work on their portfolio by the workshops (7 out of 10 interviewed). How can these two contrasting needs be combined? A solution for the next testing round could be to offer one first introductory 90-minute workshop where they learn to use all elementary functions, followed by four 45-minute workshops that take place directly after the project management lecture, to offer longer blocks to the students. In these short workshops, important functions will be deepened by solving little tasks on Mahara. At the end, we offer one concluding 90-minute workshop where students get feedback on their preliminary results and can ask final questions about the e-portfolio submission.

2.5 Mutual exchange and teamwork

Based on didactic research results [8], we identified mutual exchange and teamwork as very important aspects of our didactic concept. Therefore, every student obtained a tandem partner (by drawing lots) with whom they had to exchange communications with, at least three times, regarding the respective work progress. The result of the meetings had to be documented in the e-portfolio under the headline ‘teamwork.’ In addition, in the Mahara workshops, the students were asked to give other colleagues feedback on little tasks, or to discuss newly learned functions during the workshop.

But how did the students themselves assess this aspect? For the majority, teamwork associated with working with the tandem partner was the most important aspect (8 out of 10). One student talked about a colleague and friend, whom he worked together with on a product, and then about his tandem partner; whereas one student mainly associated the topic with the feedback he got from others in the workshop groups.

Some of the students also referred to the lecturing team, other colleagues that gave them feedback and the group exchange in the workshops, when we asked what else they connected the topic of teamwork with.

The tandem partnering system should definitely be maintained, as it was evaluated as doing ‘very well’ by the students. Eight of the ten interviewees found the feedback of their tandem partners helpful for their projects: ‘It gave me ideas like ‘yes, I'll try to put plexiglass on it.’ In any case, it helped me a lot in finding ideas.’ In the beginning, four students had the sensation that the tandem system was a bit artificial and that they only met because they were asked to do so. However, afterwards, all of them discovered that the tandem partner could give them useful advice, new perspectives on their project or orientation and an idea of where they stood compared to others.

One student, who told us that his project work did not really improve through the tandem meetings, could see a network sense in it later. He then worked together with the former tandem partner on another course, because they had already known each other from the tandem partnering. Another student, who did not give positive feedback, could not really evaluate the tandem system because his tandem partner quit the course.

The reason that the students mainly referred to the tandem partner system in the context of teamwork was probably because this was the only aspect of teamwork that the students had to document in their portfolio, which was, therefore, assessed. All of the other aspects of teamwork are important as well. Later, four students explicitly mentioned that working in little groups and providing mutual feedback was very helpful. Two of them suggested that students should be encouraged to exchange even more and get feedback on their portfolio from many different students.

To more comprehensively convey what teamwork is all about, the didactic concept for the second test round (in summer semester 2023) will be adjusted. Together with the students, we want to define different important aspects of teamwork and give them a task for each part with documentation in the portfolio. It could be that students only give feedback to their tandem partner twice. They also have to discuss certain project relevant questions in a larger group, of three to four people and document the results. They have to leave feedback on two other students on the course via the commentary function in the e-portfolio. To avoid feedback not being exchanged because of organisational problems (three students told us they had problems finding a common time to exchange), there will be reserved time slots for teamwork in the Mahara workshops.

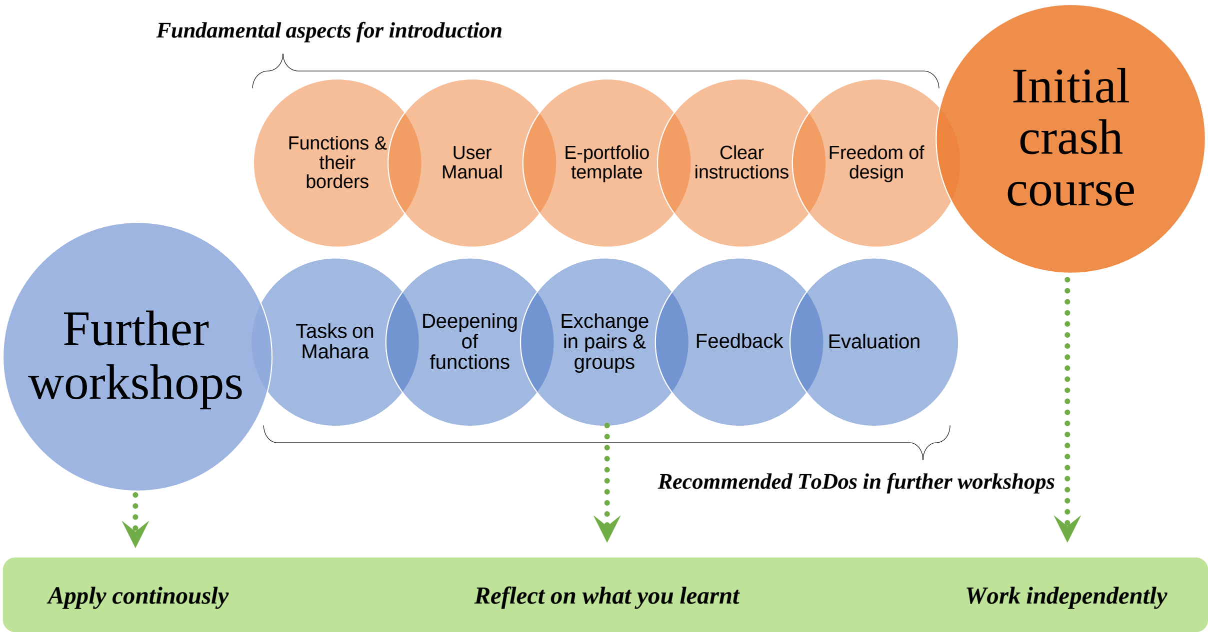

Figure 2. Didactic strategies for upcoming test course 2 (summer semester 2023)

3 CONCLUSIONS

In summary, our evaluation results lead us to the conviction that the use of e-portfolios should be continued. It offers a lot of benefits, such as a good structure and overview, freedom of design and variety, a low threshold, flexible application, more fun and less pressure.

It is important to anticipate all of the technical challenges, to enable a good acceptance of the software. Central to its introduction is to offer a comprehensive e-portfolio template that clearly explains what a portfolio can look like and what expectations the lecturers have. The accompanying e-portfolio workshops should start with a condensed crash course, to meet the needs of those who like to work quickly and independently with the software. Then, further workshop sessions should be used to deepen knowledge and to encourage continuous application. Exchanges and teamwork should be supported by mutual feedback and various tasks, in the pairs and groups that are assessed.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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REQUIREMENTS FOR TEACHING MATERIALS FOR HIGH SCHOOL STUDENTS WHO ARE UNFAMILIAR WITH THE DESIGN PROCESS

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ABSTRACT

This study evaluated the worksheets used in the Sustainable Development Goals (SDGs) Challenge Project from the students' perspective and identified requirements for teaching materials to help students who are unfamiliar with design-based learning learn about the SDGs. We analysed students' and teachers' feedback in worksheet surveys. The findings revealed that the ideation process was the most difficult aspect for high school students. The reported reasons were categorised as originality, idea diversification, idea convergence, consistency with problems, feasibility, specificity, iterability, complexity, and procedure. Teachers mentioned that students did not sufficiently focus on problem identification, causing subsequent difficulties in the ideation process. Teaching material should meet the following requirements: (1) demonstrating methods for diversification and convergence of ideas to specify scaffolding, (2) clear goal setting in the problem identification process, and (3) iterability to allow for change according to the design process.

Keywords: Design education, design process, problem identification, ideation, Japan, high school

1 INTRODUCTION

The subject of design is not taught in Japanese high school curricula [1]. The Courses of Study (curriculum guidelines) for High Schools [2] published in 2018 changed the emphasis from knowledge and skills to three educational objectives: knowledge and skills; thinking, making decisions, and expressing oneself; and self-learning and humanity in perspective. The guidelines include a newly established subject called *Period for Inquiry-Based Cross-Disciplinary Study*. In accord with these new guidelines, a new education programme was implemented from 2022. However, high schools are still in the search phase of realising integrated quality learning and have been criticised for their lack of teaching methods and materials [3]. The Sustainable Development Goals (SDGs) Design School of the Faculty of Design at Kyushu University has collaborated with public high schools in Japan to develop teaching materials for high school students to learn about the SDGs using design thinking [4] [5]. In the rapidly changing and unpredictable society, design education is expected to foster adaptability to complex social issues. This pedagogy introduces design methods into Inquiry-Based Cross-Disciplinary Study. In addition to self-directed learning, students acquire the ability to think and express themselves through the process of identifying issues and exploring solutions.

Using descriptive worksheets, Fukusho High School implemented the *SDGs Challenge Project*, a design learning programme for all third-year students, from April to October 2022. It is a typical public high school consisting of students with a mix of academic abilities. There are supportive teachers who are willing to explore the use of design education as a form of learning for high school students [1]. The whole school focused on this programme as the pilot project started in 2018, and 27 teachers with various specialisations led the classes. The teachers consisted of a combination of one teacher with experience of this programme or a veteran and one new teacher for each classroom. They were professional educators who had a good understanding of general pedagogical knowledge, knowledge of learners and their characteristics, and knowledge of the educational contexts [6] of the high school. The lesson time for the Period for Inquiry-Based Cross-Disciplinary Study was examined in this project. Prior to the start of the project, guidance was provided for teachers covering content, curriculum, educational purposes, assessment methods, instructional plans, and schedule. The rubric outlines the competences that students should acquire through this programme, in line with the three educational objectives described above. The ideal levels of achievement are: 1) to gather information and use it to solve a problem, 2) to clearly define the problem by understanding its context, and 3) to accept different perspectives and learn in an equitable manner. This rubric was explained in the introduction and included in the worksheets, which students could refer to at any time. The current study is part of a broader project exploring how design-based learning can be introduced and implemented in the Inquiry-Based Cross-Disciplinary Study curriculum in Japanese high schools. The current study evaluated the worksheets used in the SDG Challenge Project from the students' perspective and identified requirements for teaching materials to help students unfamiliar with design-based learning to learn about the SDGs.

2 LITERATURE REVIEW: INQUIRY-BASED CROSS-DISCIPLINARY STUDY

The Period for Inquiry-Based Cross-Disciplinary Study in Japan is in the early stages of implementation. The objectives stated in the Courses of Study for high schools are as follows [7]:

1. In the process of inquiry, acquire the knowledge and skills necessary for identifying and solving problems, formulate concepts related to problems, and understand the significance and value of inquiry.
2. Discover questions from the relationship between society, life, and oneself, identify issues on one's own, and gather, organise, analyse, summarise, and express information.
3. Cultivate the ability to work actively and collaboratively in inquiry, create new value, and improve society while making use of each other's strengths.

Specific educational content is to be determined by each school in line with these objectives. Tamura et al. [8] examined a Period for Inquiry-Based Cross-Disciplinary Study class and identified time constraints as an issue. Nishizawa [9] started the learning process with teachers presenting students with a trigger problem, which cut out the process of problem identification and shortened the required time because problem identification was challenging for high school students with limited experience. These studies examined evaluations from the teachers' perspective. Although various studies have surveyed university students taking teaching courses about integrated learning in junior or high school [10] [11], no studies have examined evaluations by high school students. The voices of high school students regarding the actual state of learning should be listened to.

The objectives of the Period for Inquiry-Based Cross-Disciplinary Study overlap with the design process practised by the SDG Design School. Education using design methods is not yet common in Japanese high schools, partially because of the lack of teaching materials using design methods in Japanese [4]. The current study evaluated the Period for Inquiry-Based Cross-Disciplinary Study from the students' perspective as a case study to provide a reference for high school teachers developing teaching materials when implementing this curriculum.

3 METHOD

We employed a qualitative research approach to build a case study around the SDGs Challenge Project implemented in the Period for Inquiry-Based Cross-Disciplinary Study in Fukusho High School. We examined the following research question: What do students find difficult in design process worksheets? Questionnaires were sent to 310 high school seniors who participated in the SDGs Challenge Project. Among the 30 processes (Table 1) described in the programme worksheet, respondents reported which was the most difficult and why. A comparable questionnaire was also administered to the 27 teachers who conducted the classes. The open-ended responses were categorised and interpreted to examine patterns or links in students' perceptions.

4 FINDINGS & DISCUSSION

300 students and 22 teachers responded to the question "Which of the 30 processes used in the programme worksheet was the most difficult?" The most common response was ideation, which 59 students found the most difficult of all the processes (Figure 1). The worksheet for the ideation process (Figure 2) required students to describe an idea to be realised in 2030, inspired by the latest technologies. The most common issues that students were expected to solve were the natural environment, followed by education and health and well-being. Examples of subjects under the natural environment included the negative impact of marine plastic waste on marine life, littering in the city, and damage to crops caused by typhoons. Open-ended responses regarding the reasons for difficulties with ideation were categorised using naturalistic inquiry [12] (Table 2). The results showed that, in order of most frequent

Table 1. Design processes in the worksheet

Consideration of issues	Selection of the team name Summarising content and thoughts on the reference materials Creating a mind map Exploration of problems Sharing problems Selection of a problem by the group Refining the articulation of the problem
Exploring the background of the issue	Historical perspective Social perspectives Sharing the research
Determining targets for problem solving	Whose problem is this? What is this problem about? Prospects for problem solving Group sharing
Research on case studies	Research on case studies Sharing case studies
Generating ideas for problem solving	Ideation Deepening ideas Sharing ideas Summarising ideas Creating a poster
Validating ideas	Third-party verification of ideas Thinking about the problems of ideas Improvement of ideas Improvement of poster
Preparing a presentation	Determining presentation role assignments Creating a PowerPoint presentation Improving posters and prototypes
Toward the final presentation	Idea improvement Creating final presentation poster

responses, originality (15 respondents), idea diversification (12 respondents), idea convergence (nine respondents), consistency with problems (six respondents), feasibility (four respondents), specificity (four respondents), iterability (three respondents), complexity (one respondent), procedure (one respondent), and other (four respondents) were identified.

The same questionnaire was also administered to the teachers who conducted the programme. Of 27 teachers, 22 responded (Figure 3). The most common response was "exploration of problems around us" by five respondents, followed by "selection of problems in groups" (four respondents) and "ideation" (four respondents). One teacher who chose ideation reported that "because students defined the problems abstractly, it was difficult for them to imagine, and the ideas were shallow. No matter how much they discussed problems, they could not seem to avoid vague themes, such as hunger and poverty in other countries, and could not come up with solutions". Three of the four respondents who selected ideation cited the vagueness of problem identification as the reason. Teachers who reported the most difficulty in the problem identification phase gave the following reasons: "At this stage, students did not have a clear idea of what the problems would be, and I felt that they gradually understood the meaning from the later processes (historical perspective or social perspectives)"; "It was hard to identify target users and to consider solutions afterwards, because the problems were not sufficiently focused on a forward-looking perspective."

5 CONCLUSIONS

The evaluation of the worksheets used in the SDGs Challenge Project from the students' perspective revealed that many students found the ideation process difficult. Requirements for teaching materials were categorised as follows: (1) demonstrating methods for diversification and convergence of ideas to

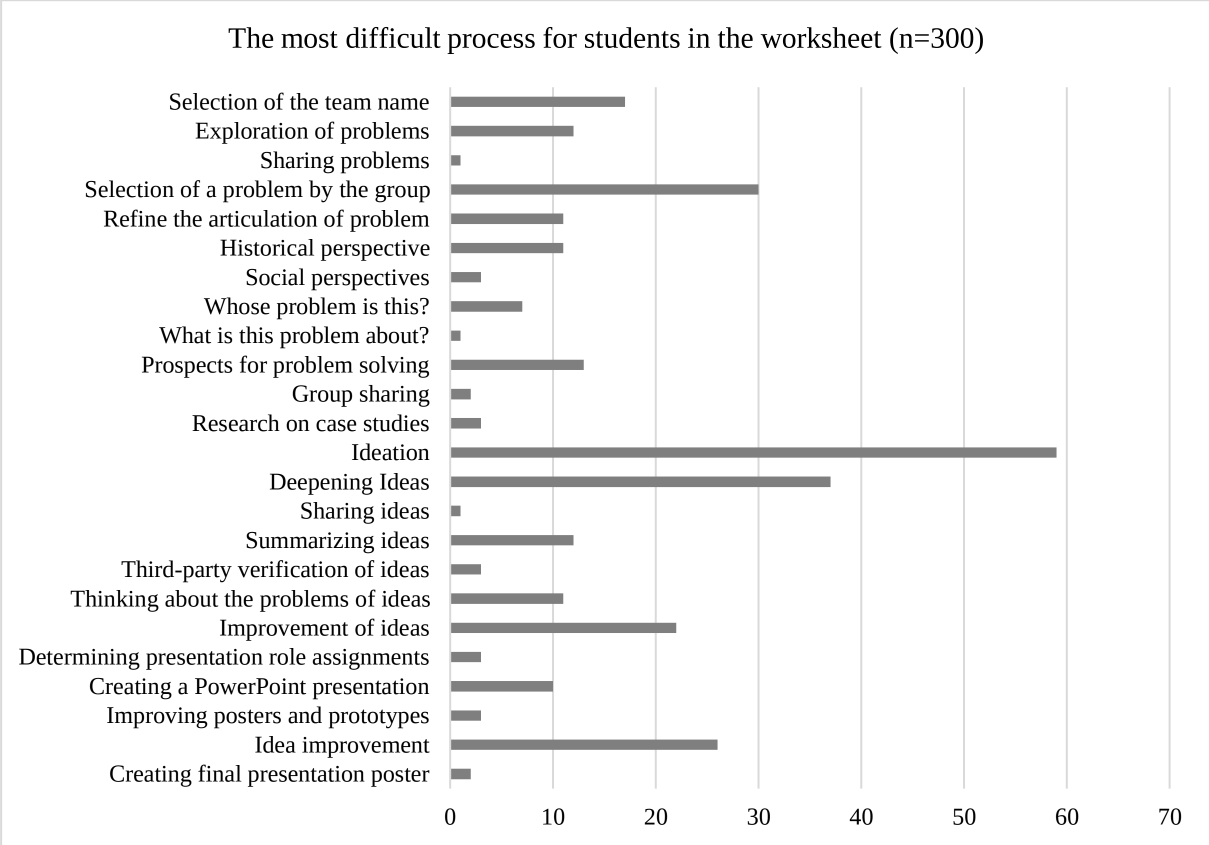

Figure 1. Students' feedback on the worksheet

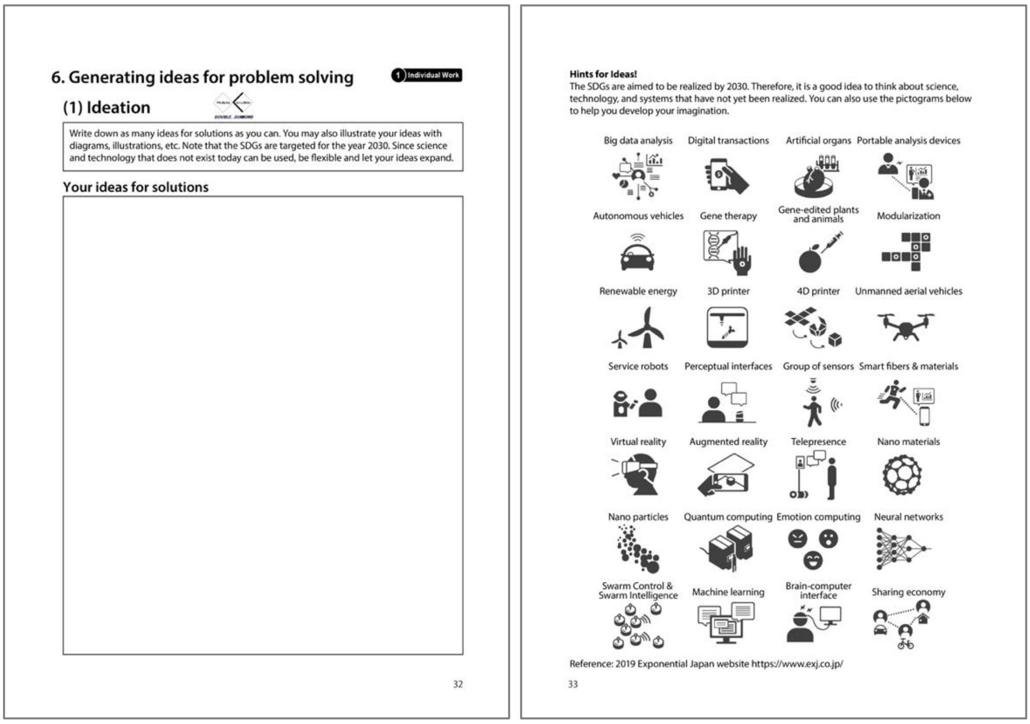

Figure 2. Worksheet for ideation adapted from Reference No. 13 translated into English

specify scaffolding, (2) clear goal setting in the problem identification process, and (3) iterability to allow for change according to the design process.

First, students did not know how to undertake tasks in the idea divergence, idea convergence, and procedure categories. The worksheet for the ideation process was open-ended. This approach proved

Table 2. Challenges faced by students in the ideation process

Category	Reasons
Originality (15)	It was difficult to come up with original ideas because some of the ones I came up with were not new or were similar to those of other groups.
Idea diversification (12)	I couldn't come up with any ideas.
Idea convergence (9)	It was difficult to come up with ideas because everyone had their own ideas, and it was difficult to focus on just one.
Consistency with problems (6)	The ideas did not match the problem.
Feasibility (4)	Some of the ideas that came up were infeasible or had many disadvantages, and it took a lot of time and thought to come up with ideas that everyone in the group could agree on.
Specificity (4)	It was difficult to come up with specific ways to solve problems, even though we identified a lot of them.
Iterability (3)	Even when we came up with ideas, flaws were often quickly found and rejected.
Complexity (1)	Finding a solution created gaps with people who were not subject to that solution.
Procedure (1)	It was difficult to know where and how to start.
Other (4)	It was difficult.

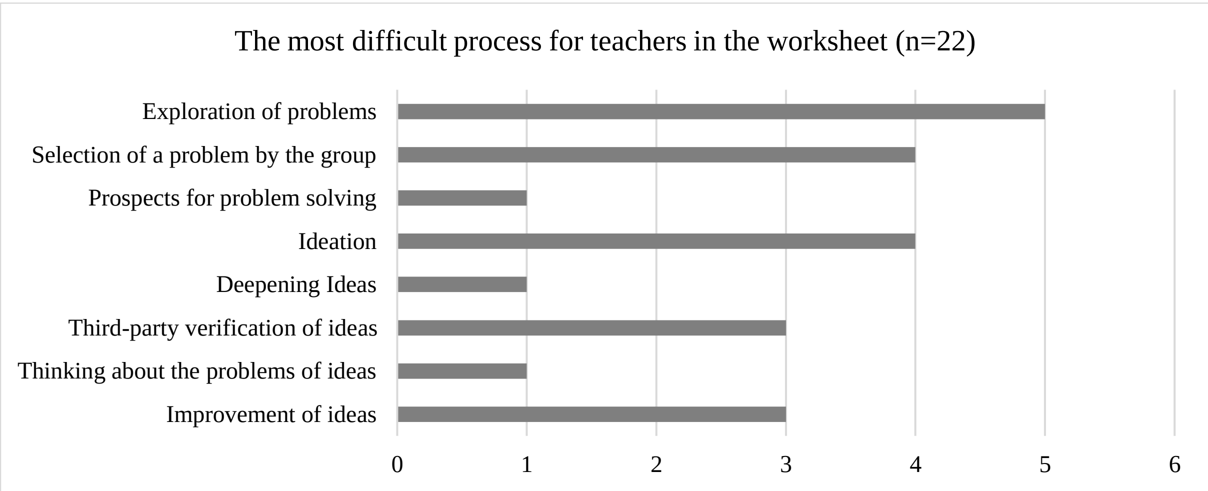

Figure 3. Teachers' feedback on the worksheet

difficult for students who were unfamiliar with design-based learning. It is necessary to demonstrate methods for diversification and convergence of ideas, how to perform each step, and to specify scaffolding so that students can work autonomously in groups.

Second, as pointed out by teachers, ideation can be affected by an insufficient focus on the problem in the problem identification process, which is the preliminary stage of ideation. Consistency with the problem category showed that it was difficult for students to connect problems and ideas. Thus, the problem identification process is critical. The goal of the process must be clarified, and the problem should be clearly described in detail, identifying whose problem it is, enabling high school students to relate it to their own experiences.

Finally, the categories of originality, feasibility, specificity, iterability, and complexity showed that students are unfamiliar with the characteristics of the design process. In the design process, ideas are realised not through a one-way process but through back-and-forth iterations to solve complex problems. For high school students, it was difficult to create original ideas and consider feasibility while following such a complex process. The survey responses confirmed that students came up with ideas but gave up on them, assuming that they had already been implemented in society or that they were unlikely to be realised. Thus, students stopped at the first round of the iterative process, which is critical to the design process. To improve the ideas generated by students, it is essential to strengthen originality and feasibility through further group discussions, advice from teachers, and additional research. For example, it is difficult to come up with a completely new idea from scratch, but it is possible to develop a new idea by combining existing ideas. The worksheet did not accommodate this iterative process because it was formatted for students to write down ideas once then move on. Thus, the worksheet should allow for additions and flexible changes according to ideas generated by students.

Shulman [6] described the seven categories of the knowledge base for teacher as content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Of these, the development of teaching materials of this study was able to contribute to the categories of curriculum knowledge and knowledge of educational ends, purposes, and value. However, the pedagogical content knowledge for teachers needs to be improved, as evidenced by the fact that the students did not understand the specialized methods unique to the design field. For future study, elucidation of how to present the design process for instruction is necessary.

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EVALUATION METHOD FOR ASSESSING STUDENTS' QUALITY OF CRITICAL THINKING IN THE IDEATION PROCESS THROUGH DESIGN JOURNALS

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ABSTRACT
This study aims to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. The critical thinking model by Paul and Elder is used as a foundation to create a means to evaluate students' critical thinking. This study creates a case study using the self-study approach as a purposeful sampling strategy. As a self-study approach, the author's experience in conceptualising an evaluation method to assess students' quality of critical thinking documented in the design journal was examined. Using a design journal from a Singapore secondary school, the author presented a method to contextualise the intellectual standards based on teachers' expectations for the design project. The intellectual standards are used to evaluate the reasoning process of the student through the documentation in the design journal.

Keywords: Critical thinking, design education, design and technology, ideation, assessment

1 INTRODUCTION
Design and Technology (D&T) is offered as general education subjects in secondary school education, where students may be exposed to design education such as visual communication design, product design, and textile/fashion. In D&T projects, students often experience and participate in inventive and creative processes to develop new ideas to solve real-world problems. Students are often exposed to unfamiliar contexts when developing new ideas to solve design problems. Students' decision-making process when generating creative ideas is often flawed due to their assumptions that can be influenced by cultural, biological, social, political, theological and historical factors [1]. While facing unfamiliar contexts when designing, students require critical thinking to critique their assumptions and rationalise their decision-making when designing solutions to solve a design problem [2].

In Singapore education, critical thinking and inventive thinking are recognised as vital to helping Singapore's young people strive in the 21st century. Thus, D&T in Singapore aimed to cultivate students' critical thinking through design-and-make projects. In design-and-make projects, students are required to identify design problems, ideate, develop ideas, and realise a working prototype. In the projects, students record their thought processes in design journals. When assessing students' design journals, there is a lack of clear standards and methods to evaluate the quality of students' critical thinking. However, few studies have been done to determine how critical thinking can be systematically assessed through design journals. This study aims to adopt a qualitative research approach to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. Focusing on Singapore D&T, this study will clarify a method to unpack students' critical thinking process in ideation and then assess students' critical thinking through design journals. From the outcomes of this study, teachers can then understand students' reasoning process and provide formative assessments to guide them to correct any flaws in their thinking process.

2 DEFINING CRITICAL THINKING AND EVALUATION OF CRITICAL THINKING
As the objective of D&T is to offer as general education, critical thinking developed through D&T should be transferable across different domains. This study will adopt a generalist approach in exploring the definition for critical thinking. Critical thinking can be conceptualised according to the generalist

(domain-general) and the subject specific (domain specific) approach [3][4][5]. The generalist approach conceptualises critical thinking as a set of skills that may be applied across subjects and disciplines. Although the definitions of critical thinking are varied, most definitions tend to overlap each other considerably [6]. Most definitions of critical thinking include reasoning/logic, judgment, meta cognition, reflection, questioning, and mental process [7]. One of the mainstream concepts of critical thinking was developed by Ennis [8][9][10]. Based on Ennis, critical thinking can be conceptualised through the decision-making process in problem solving. In problem solving, the decisions about belief or action are made through inferences based on observations, information and/or some previously accepted propositions. When making and checking decisions independently, an ideal critical thinker should exercise a group of critical thinking dispositions and abilities where any decision made should be justifiable and able to be articulated to others [11]. In general, measurement of critical thinking skills and dispositions mostly come in the form of test-based assessments.
Paul and Elder provided an alternative model for assessing the quality of critical thinking [12]. The assessment model by Paul and Elder is based on the definition where critical thinking as a disciplined process that actively and skilfully conceptualise, apply, analyse, synthesize, and/or evaluate information gathered from/or generated by observation, experience, reflection, reasoning or communication, to guide one's belief and action [13]. The conceptualisation of critical thinking by Paul and Elder rest on the basis that thinking can be analysed and evaluated by first taking thinking apart and then applying standards to those parts. Paul and Elder explained that whenever thinking occurs, reasoning occurs. This is based on the concept that thinking always occurs for a purpose within a point of view based on assumptions that lead to implications and consequences. Concepts, idea and theories are used to interpret data, facts and experiences in order to answer questions, solve problems and resolve issues. As such, all thinking processes involve generating *purposes*, raising *questions*, using *information*, utilizing *concepts*, making *inferences*, making *assumptions*, generating *implications* and embodying a *point of view*. These eight areas form the eight basic structures of thinking, which Paul and Elder also called the elements of reasoning that are present in reasoning across subjects and cultures. By deconstructing thinking into the elements of reasoning, each element of reasoning may then be assessed.
Paul and Elder suggested that a well-cultivated critical thinker exhibits the following characteristics.

- Raises vital questions and problems, formulating them clearly and precisely.
- Gathers and assesses relevant information and effectively interprets it.
- Generate well-reasoned conclusions and solutions, testing them using relevant criteria and standards.
- Thinks open-mindedly within alternative systems of thought, recognizing and assessing as need be, their assumptions, implications, and practical consequences.
- Communicates effectively with others in figuring out solutions to complex problems.

The formation of these characteristics is based on a conceptual framework where the basic structures of thinking, also called elements of reasoning, can be assessed using a set of standards (also called intellectual standards). Elder and Paul explained that intellectual standards can be conceptualized as standards necessary for making sound judgements and rational understanding [14][15][16][17][18]. The intellectual standards are formed based on the argument that all modern natural languages (such as English, German, Japanese, etc.) provide their users with a wide variety of words that, when used appropriately, serve as plausible guides in the assessment of reasoning. Words such as clarity, accuracy, relevant, significant, logical and so forth are identified as intellectual standard words. Though the focus on determining intellectual standard words is based on the availability in English language, it is hypothesized that similar web of intellectual standard words exist in every natural language, though perhaps with differing nuances. Paul and Elder suggested that there are at least 9 intellectual standards (also called intellectual standard words). The intellectual standards are *clarity*, *accuracy*, *precision*, *relevance*, *depth*, *breadth*, *logicalness*, *significance* and *sufficiency*. Using questions to deconstruct reasoning, a framework of how intellectual standards can be applied to these questions to assess quality of critical thinking is further explained through Paul and Elder's model of critical thinking.

3 RESEARCH METHODOLOGY

3.1 Research questions and method of inquiry

Two key research questions sort to be answered. Firstly, how do we unpack students' critical thinking process during ideation through the design journal? Secondly, upon unpacking students' critical thinking processes, how do we evaluate the quality of students' critical thinking processes during ideation through the design journals? Through the literature review, Paul and Elder provided a clear structure to unpack reasoning into parts. Without using test-based assessment, Paul and Elder's model allows the quality of reasoning to be assessed using intellectual standards that can be contextualised based on context. With the above considerations, this study adopts the critical thinking model by Paul and Elder.

This study applies a qualitative inquiry strategy based on the principle of purposeful sampling to create a single significant case study. This case study will use a self-study approach as the purposeful sampling strategy. Purposeful sampling is where the cases for study are selected because they are information-rich and can provide deep insights into the phenomenon [19]. As a self-study approach, one's own experience of a phenomenon will be examined. This study will examine the author's experience in conceptualising an evaluation method to assess student's quality of critical thinking documented in the design journal. Singa Secondary School (school name is a pseudonym) in Singapore was selected for this study. Singa Secondary School was selected because the D&T fraternity in Singapore has recognised it for innovation in pedagogy and teaching practices. Though the school has a student profile of a mix of academic abilities, the D&T program has consistently achieved excellent student outcomes.

3.2 Research design and implementation

This study is designed and implemented around Design Journal X done by an upper secondary school student in Design Project A. Design Project A is a major design project that all upper secondary school students in the Express course (between the age of 15 and 16) have to go through in Singa Secondary School. In this project, each student will produce a design journal. Design Project A aims to allow students to apply knowledge and skills learned in D&T to engage in a full design process that starts with a given theme and ends with a working prototype. Teachers are mainly supervisors as students are mainly self-directed during the design process. Students are required to record any forms of idea explorations, research, and evaluation processes related to ideation in the design journals. Thus, it is assumed that each student’s thinking and decision-making processes will be recorded in the design journal. Design Journal X was selected based on the rationale that the design journal is a representative sample that reflects the quality of work done by most of the D&T students in Design Project A. The design journal selected for the study is not an outlier in terms of performance.

4 RESEARCH FINDINGS AND DISCUSSIONS

The critical thinking model by Paul and Elder can be applied to all reasonings across different fields, but the importance of some intellectual standards may be different in different fields. Thus, it is necessary to contextualise the intellectual standards within the field and then articulate the intellectual standards that are most important for reasoning. To have a context to contextualise the intellectual standards relevant to the ideation process, the author consulted the D&T teachers involved in Design Project A and collected their expectations of students in generating ideas for this project. Refer to Table 1. These expectations were in line with the assessment rubrics for Design Project A.

Table 1. Teachers’ expectations for students during the phase of generating ideas

Teachers’ expectations of student in generating ideas
The student generates ideas that can solve the chosen problem.
The student generates as many ideas as they can. This is to ensure that students explore different possibilities in solving the problem. There are no specific expectations on the number of ideas generated.
The student generates ideas to solve the problem in different ways.
The student generates ideas that are practical and probable to solve the chosen problem.
The student elaborates on each idea clearly and logically through sketches and annotations to clarify how the idea can work and how users can use it.
The student generates ideas that are not plagiarized from existing or someone’s idea.
The student generates ideas that cater to the needs of the users and also satisfy the design specifications.
The student generates new ideas that has not been seen in the market through their research.
The student evaluates the ideas to identify the potential negative and positive implications or consequences.
The student gives clear and logical reasoning in the choosing the idea(s) to develop further.

Based on teachers' expectations, the author crafted the questions and used them to deconstruct the reasoning process for ideation. In consultation with the D&T teachers, the author drafted the good reasoning traits related to the ideation process. Refer to Table 2. These good reasoning traits will be labelled intellectual standards for good reasoning when generating ideas.

Using the intellectual standards articulated in Table 2 as criteria to assess quality reasoning, the author observed student's reasoning processes during ideation by interpreting the documentation in the Design Journal X. Documentations referred to any form of scribbling, images and sketches in the design journal that constitutes to supporting the reasoning process of the student. In addition, the author also looked out for any parts deemed as faulty reasoning. To increase validity of the interpretations, any queries related to the documentations were clarified with teachers before further interpretations.

The design problem and the design brief below provide the context of what the student is designing.

- Design Problem: *Currently, many homes often face the problem of having too many wires of electronic devices at the desk area at homes where laptops and charging wires are usually kept. Many wires means that they can get entangled easily and therefore it may result in a hassle for the user to untangle the wires. (original text written in the design journal by student)*
- Design Brief: *To design and make a product to help people organize the various wires of their electronic devices so that it helps to prevent the wires from getting tangled and is visually appealing as well. (original text written in the design journal by student)*

Table 2. Intellectual standards for good reasoning articulated to access critical thinking in ideation

Elements of reasoning	Questions to deconstruct reasoning	Intellectual Standards for good reasoning when generating ideas
Purpose	Is the student clear about the purpose of generating ideas to solve the problem?	Display clarity in purpose by showing consistency in addressing the problem when exploring ideas to solve the problem.
Question	Is the student able to ask relevant questions that lead to solving problem when generating ideas? Is the student able to use relevant questions to evaluate the ideas? Is the student able to clarify workability of the ideas using relevant questions? Is the student able to use relevant questions to elaborate the ideas?	Relevant questions are used to generate the ideas. Relevant questions are used to assist student when elaborating the ideas clearly. Relevant questions are used to evaluate the ideas generated. Ability to breakdown the main question into sub-questions to achieve a more precise clarification of the main question with respect to the ideas generated. Relevant sub-questions are used to generate ideas. Relevant sub-questions are used to clarify the ideas generated.
Point of View	From what point of view did student generates the ideas? From what point of view did student evaluates the ideas?	Generating ideas based on other points of view to achieve clarity, relevance, and breadth. Evaluating ideas based on other points of view to achieve clarity, relevance, and fairness.
Assumptions	Are the student's assumptions justifiable and reasonable based on evidence or past experience? Is the student clear about the assumptions that he/she is making?	The workability of the ideas is based on assumption that are justified, reasonable and/or clear.
Information	Does student ultilise relevant information to support his/her claim on the workability of the ideas?	Source of information to support the workability of ideas is relevant, reliable and accurate.
Concepts and Ideas	Is the student able to use concepts to explain the workability of the ideas?	Display clarity, relevance and accuracy in using concepts to justify the workability of the ideas.
Implications and Consequences	Is the student able to anticipate the likelihood of the potential negative and positive implications? Is the student able to clearly and precisely articulate the possible implications and consequences?	Display clarity and logicalness in anticipating the possible implications and consequences of the ideas generated. Display clarity and accuracy in articulating the implications and consequences on the ideas generated.
Inference	Is the student able to make inferences that are justified, reasonable, clear and logical during the process of generating ideas? Is the student able to make inferences that are justified, reasonable, clear and logical when evaluating ideas?	Display justification, reasonability, clarity and logicalness in making inferences when generating the ideas. Display justification, reasonability, clarity and logicalness in making inferences when evaluating the ideas.

With intellectual standards, student's reasoning can be dissected and observed in detail. Each observation that constituted quality reasoning is tagged, and notes are recorded. An example is shown in Figure 1. Short notes or keywords are used as a general "code" to consolidate similar traits related to a particular element of reasoning. The number of times quality reasoning is evident in the documentation are also recorded. Similarly, weak reasonings are also tagged and recorded. From observing and interpreting the documentation, each observation is considered a tag. Table 3 shows the number of tags in the design journal that showed quality and weak reasoning.

The intellectual standards created for this study allowed student's reasoning process to be studied in detail based on the number of tags made through the documentation. However, reading through all the scribbling and sketching can be time-consuming. Nevertheless, if supervising teachers monitor students' progress constantly, it may not be tedious as only bite-size information will be studied.

In this study, it is observed that not all reasoning processes can be articulated in words. Sketches are also essential languages for students to articulate their thought processes during ideation. Thus, teachers should also study students' sketches in detail to highlight instances when questionable concepts and unjustified assumptions are used to create new ideas.

Some concerns and limitations were surfaced when evaluating students' critical thinking. Firstly, evaluations may be hampered when documentations are few in the design journals. This method is only as effective as the content that is documented in the design journal. Secondly, the articulation of the intellectual standards will be varied based on the student outcomes of each project. But the fluidness of articulating the intellectual standards based on context may also be a strength where teachers can apply this method of evaluating students' critical thinking according to their project setting. Thirdly, the intellectual standards are mainly articulated by the author in consultation with the D&T teachers involved in the project. The intellectual standards applied in this study should undergo verifications by other D&T teachers and/or experts so that the standards can be more robust for evaluating students' critical thinking in ideation. Lastly, the current evaluation method does not provide a detailed analysis of students' level of quality reasoning. The current method can only provide a general indication of whether students exercise quality reasoning. Further research on developing relevant rubrics that compliments the current method to measure the level of quality reasoning is required.

Observation and interpretations of design idea:
- Demonstrate clear purpose when generating ideas.
- Consistent with purpose when generating ideas.
- Application of well-reasoned concepts in idea.
- Clear, relevant and accurate presentation of concepts to explain idea's workability.
- Made good assumptions on workability.
- Idea was adapted from earlier product analysis. Student demonstrated the use of relevant, accurate and reliable information to apply in the idea. Student also made reasonable and logical inferences in the earlier product analysis to apply workable concept to solution.

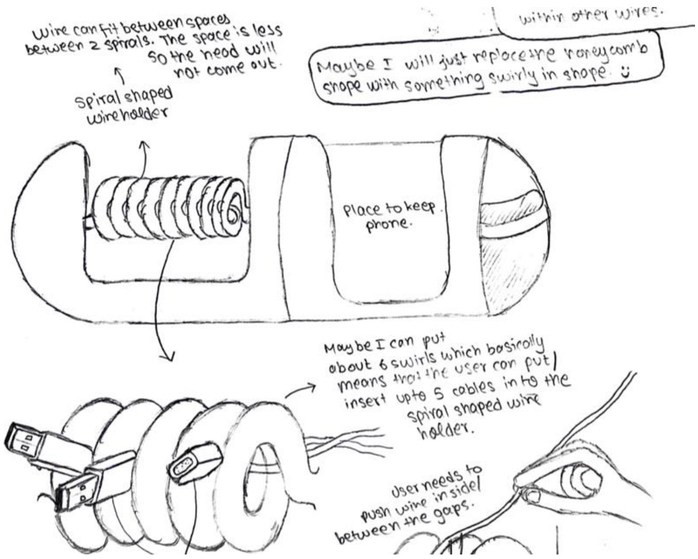

Figure 1. An example of an observation for good reasoning that is tagged in the design journal

Table 3. Quality of reasoning displayed by student in the design journal when generating ideas

Quality reasoning displayed during ideation based on intellectual standards in Table 2 (described by keywords/shortnotes)	Number of tags where student demonstrated good reasoning based on the intellectual standards for ideation	Associate to which element of reasoning?
Demonstrate clear purpose when generating ideas	23	Purpose
Consistent with purpose when generating ideas	23	
Use relevant question when generating ideas	13	Questions
Use relevant question when evaluating ideas	2	
Seek opinions when generating idea	1	Point of View
Made good assumptions on workability	36	Assumptions
Using relevant information when generating ideas	5	Information
Using reliable information when generating ideas	5	
Using accurate information when generating ideas	5	
Using information to justify ideas	5	
Different source of information when generating ideas	1	
Application of well reasoned concepts in idea	23	Concepts and Ideas
Clear presentation of concepts to explain idea	23	
Anticipate implications and consequences	17	Implications and Consequences
Articulate implications and consequences	7	
Make good inference based on information	4	Inference
Weak reasoning displayed during ideation based on intellectual standards in Table 2 (described by keywords/shortnotes)	**Number of tags where student demonstrated weak reasoning based on the intellectual standards for ideation**	**Associate to which element of reasoning?**
Inconsistency with purpose	2	Purpose
Unclear and unjustified assumptions	3	Assumptions
Questionable concepts used in idea	2	Concepts and Ideas
Implications and consequences are not justified	6	Implications and

5 CONCLUSIONS

This study aims to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. Using the critical thinking model by Paul and Elder, the author presented a method to contextualise the intellectual standards based on teachers' expectations for the design project. Using the intellectual standards created, students' reasoning process may be studied and evaluated through the documentation in the design journal. Several limitations were surfaced. Firstly, limited documentation in the journals will affect the evaluation process. Secondly, more verifications of the intellectual standards by other D&T teachers and experts are required. Lastly, the current method cannot measure students' level of quality reasoning. While the limitations in this study set the themes for future research, the author also intends to apply the current evaluation method to clarify the trend in students' general quality of reasoning in ideation by using a collection of design journals that Singa Secondary School can provide.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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UNDERSTANDING MATERIAL CULTURE: EMOTIONS, MAKING AND VALUE, A PRODUCT DESIGNER'S PERSPECTIVE

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ABSTRACT

The concepts of emotion, making and value, while not new or alien to the researchers in design, have been looked at mainly from the point of view of end user of the design. This paper aims to discover and understand these concepts and their relationship with each other from the point of view of cultural anthropology and tries to compare and relate these two points of view to product design discipline. The understanding of the topic here is based on the review of papers published by various anthropology researchers and ethnographers on the work of studies in material culture and ethnographic studies as well as a design study conducted to experience the multidisciplinary approach towards product design. In the review the authors discover and discuss the social aspects of emotions, making and value and the way they are connected to each other socially, through material creations. Authors go on to visually illustrate their understanding of the hierarchy of human-object relation and the activities and the value associated with the five states of this relation. This understanding is discussed through the lens of emotional product design, design research and business research to expose some significant areas of knowledge creation for the increasingly unsustainable world. These opportunities of knowledge creation, at the intersection of cultural anthropology and product design, are discussed for the benefit of product design practice and product design education.

Keywords: Emotional design, making, shared emotions, object biography, multidisciplinary approach

1 INTRODUCTION

The interdisciplinary studies involving product design and cultural anthropology promise to provide a new and interesting perspective to the ongoing work in emotional product design. The concepts of emotions, making and value (of objects) have been studied, either independently or together, in various disciplines like anthropology, history, sociology, archaeology, psychology, design and business. So different aspects of emotions, making and value are unravelled by the researchers working in these disciplines. This paper tries to explore and understand some of these differences, with materiality as the central theme binding them with the discipline of product design.

Emotional product design, being part of product design discipline, aims to deliver physical object outcomes for meeting functional as well as emotional needs of a particular target group of users, especially the ones encountered while making choices for acquiring new products. Buying decisions mostly being individual, the current focus of emotional product designers and design and business researchers is mainly on studying the individual human-object emotional relations, in before-purchase scenarios.

In recent times, the focus of researchers in design, business and environment has been strongly shifting towards concepts of sustainability, sustainable behaviours and circularity etc. in a steadfast manner, with the hope to engender ways to minimise the environmental damage being caused by introduction of new objects to the world at a very alarming pace. However, the current approach of emotional design, directed towards individual human-object emotional relations in before purchase scenarios, is aimed at influencing higher and quicker buying decisions. This is contradictory to the higher common intention of working towards sustainable user behaviour, especially through emotional product design.

The approach in cultural anthropological studies on emotions, of considering the social aspects of human-object emotional relations over the entire time of life of the product, e.g., through object biography [1], [2], [3] seems to be more aligned and promising if the designers and researchers wish to connect emotional design to sustainable behaviour. The design students being future stakeholders of design process, need to look at products beyond their physical and functional aspects, using multidisciplinary approach and tools like object biography etc. This paper aims to explore some of these multidisciplinary concepts and approaches through literature review of some papers published on the studies in material culture and look at the understanding derived from the point of view of product designer. A design study was also conducted to experience the understanding of these approaches.

2 ANTHROPOLOGICAL APPROACHES TO STUDIES IN EMOTIONS

While majority of the researchers studying emotions understand that "the emotions are both biological and cultural in nature" [4], there is a difference in approaches towards studying emotions, based on where the emotions are considered to be located with respect to the human being and how they are evoked. With the psychological approach it is considered that the emotions are very much located in the human brain, and it is the action of hormones that causes the bodily expressions of emotions in human beings. This biological approach points to the universality of the emotions and is widely used as applicable to all human beings sharing the modern anatomy.

However, the anthropological approach based on constructivism, considers the emotions to be located not only in the human bodies but also in the objects, places and the environment surrounding them. This approach points to the emotional experiences which are not universal but cultural and social in nature and has a great influence on the way the emotions are experienced and expressed.

Object biography [1], [2], [3] is a methodological tool to understand the relation between the object and people, by studying the life of an object from its birth (production) to death (state of no relation with people). Each object has a story of its own to tell and this study helps reveal the changing nature of relations the object has had with people and the way it has aged with its changing surroundings. Introducing object biography to product design students can potentially widen the horizon of their understanding of designed objects beyond 'before purchase scenarios' to post-purchase or 'during use' scenarios.

The approach of material culture is looked upon [5], [6], [7] as equivalent to studying historical text, as it provides the material proof of how human beings experience the world around them. The purpose of material culture study is also to understand the human behaviour and the various factors affecting the choices they make while interacting with physical objects, the factors like social forces, economic aspects, technological advancements etc. The material culture of a group, community or region in a particular time frame can reveal the shared emotional status of people in that context. Referring to the material culture of the in-patients' room in a psychiatric unit, [8] calls it the 'material culture of hope'. These patients, hoping for their stay in those rooms to be short and temporary, do not tend to decorate or elaborate the rooms with physical objects. The nature of objects in these rooms highlights the possibility of temporary occupancy for all these patients sharing the emotion of hope. Emotional communities and communities of enthusiasm are two more interesting concepts based on this idea of shared emotions, discussed in next section.

3 EMOTIONAL COMMUNITIES AND COMMUNITIES OF ENTHUSIASM

A ritual, e.g., the one at cemeteries, is an example of shared emotional experience where multiple people simultaneously go through similar emotional state. Cemetery is also an example of a place where the emotions are experienced and expressed in a social manner. Nilsson Stutz [9], in her study related to Mesolithic mortuary practices, claims that emotions give meaning and memorability to the rituals and in turn to the cemetery place, making the place "sticky" with emotions [10], [11]. The emotionality of spaces and objects helps bring and keep the people sharing those emotions together in a particular time frame, in the form of emotional communities [12], [13], a concept suggested by Rosenwein.

The concept of communities of enthusiasm can be understood as a group of people seeking activities and experiences for pleasure and not monetary benefits, like hobbies and hobbyists [14]. Pleasure or joy being an experience of emotion, it can be said that enthusiasm is an emotional relation. The communities of enthusiasm involve sharing and exchanging knowledge and skills [15] with each other, eventually strengthening the bonds within community. The emergence and accretion of these communities, especially the ones based on objects, ensure that those objects are collectively kept alive and kicking for a much longer time than expected. This is convincingly elaborated by DeLyser and Greenstein [14] with their example of restoration of the motorcycles by the Indian Motocycles company in America. The community around these motorcycles kept them running, usable and valuable for many years after the company discontinued the production. The concept of enthusiasm also revolves around individual and shared activities and experiences involving relations with material things, hinting towards ‘making’ as one of the most significant themes for the communities of enthusiasm.

4 MAKING AND BECOMING OF AN OBJECT

The Anthropocene world has abundance of man-made material creations, eventually becoming a part of our environment, our life. Humans have been making objects even in stone age, and making as an activity is the most intimate and involving type of relation a person can have with material.

Making as a transformative interaction between object and person, exacts skills, knowledge and imagination and can reveal the relation between material and skills, thing and person [16]. Objects are either made individually as craftwork or made in large number by mass manufacturing, with the craft making considered as “founded in the art of care”, the care referring to the one people exercise for other people [17].

While making generally refers to transforming materials into new objects, as a material interaction between people and object, making can also refer to activities like cleaning, maintaining, repairing, modifying, repurposing and restoring, as these activities do help the object ‘become’ something in its own social life. The emotional relation between people and objects during these various making activities, as understood by authors, is of varying nature (Figure 1) and so is the nature of value associated with making.

The human-object relation usually starts with the person acquiring the object e.g., through monetary exchange (buying) or as gift etc. and the relation is that of ‘right to use’ which the authors call ‘dominance’. Over the time of use, the relation matures to that of coexistence and caring through simple cleaning, maintaining etc. to be called the relation of ‘expectation’, where it is expected that the relation will continue to exist. With passing of time, the objects age, undergo wear and tear and may lose some aesthetic or functional features over time. At this stage, there is relation of mutual ‘hope’ where both the person and the object hope to continue to enjoy the now meaningful emotional relation through activities like repair, modification and updating or replacing some parts. At this stage of hope, the relation also starts gaining some social and emotional value, by the virtue of interactions with multiple people and objects involved in these activities.

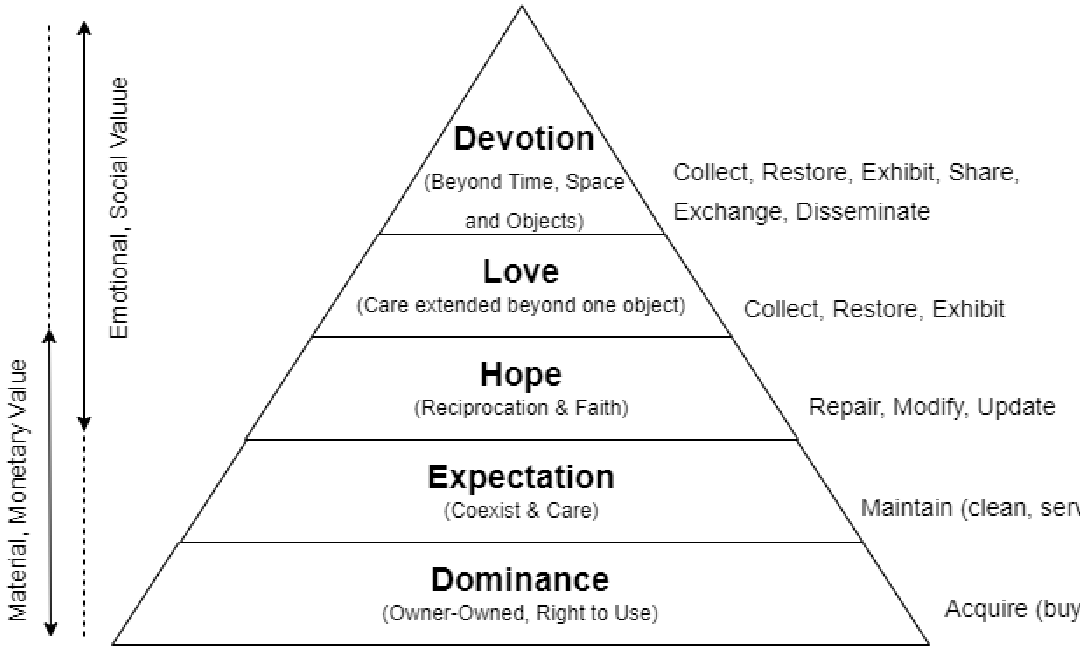

Figure 1. Hierarchy of human-object relation, as understood by authors

The phase of ‘relation of hope’ is very significant because the positive results of the activities of hope, can lead to people extending the faith in a particular product to other similar products, category, the brand and the industry in general. This can lead to people acquiring other products of the particular type or brand and hoping to have an equally fulfilling and pleasurable relation with them. The activities then go beyond buying and repairing to seeking, collecting, restoring the dying ones and even exhibiting the prized possessions for others to see. This is the stage that can be called the relation of ‘love’ between people and objects. This stage has a much higher social and emotional value as compared to the monetary values of the objects and can be witnessed when people say they love the products of a particular brand or type and are excited to see others possessing those.

The highest state of the human-material relation is the one very appropriately termed as ‘devotion’ [14] and is very well elaborated in their ethnographic study of the restoration of three motorcycles discontinued by the Indian Motocycles company. What differentiates this relation of devotion from that of love is that the activities involved go beyond ‘collect, restore and exhibit’ to the ones involving sharing and exchanging of knowledge and skills with other people of same or different region, age or even generation, disseminating the experience of this relation to a much larger frame of time and space. Of the five states of human-object relation discussed above, devotion, being based on the enthusiasm driven making and dwelling within the emotional communities, is the most social type of material relation people can experience.

The hierarchy of human-object relation described by the authors above, if studied, elaborated or challenged by the researchers can result in the knowledge about various material and non-material factors influencing the transition of this relation and the associated value of making from one state to the higher one.

5 THE VALUE OF MAKING

The value of making can be transformative in nature [18], meaning the act of making can transform the materials into something of monetary value i.e., worthy of exchanging for money or it can transform the materials into something which also has some social or shared emotional value i.e., worthy of social praise or exhibition. While there could be many reasons why people make something, making as an activity is taken up by people for reasons of earning money, as a means of deriving pleasure or even as a learning endeavour, and the value of the outcome depends on these reasons to an extent. A person who has maintained his old car in ‘like new’ condition, not only earns some praise in his social circle, but his emotional relation with the car is materially evident in the aesthetics of the car, which if sold will command a higher monetary value too. Value of making is thus a direct reflection of the emotional relation between the person and the object, whether the value is material, monetary type or social and emotional type, as illustrated by authors in the previous section.

6 COOKWARE DESIGN STUDY

To demonstrate and experience the effect of using the new interdisciplinary approach on the outcome of product design process, a design study was conducted for commercializing a traditional Indian recipe through cookware design. In Figure 2 the design on left was created in the past following the conventional product design process which focused on coming up with an efficient and commercially scalable, automation friendly way of cooking sunga (bamboo) chicken. While these aspects were addressed to a good extent, the experience of authentic Indian cooking was lost. So, in the design study, a new sunga cookware was designed which focused on keeping the experience of authentic traditional Indian cooking intact without compromising the efficiency and commercial aspects. During the design process, aspects like shared emotions around the Indian way of cooking, the material culture of traditional Indian cooking were studied and considered to be manifested in the form of choices for material, colour and form of the cookware, the product architecture and the ritualization of the cookware usage itself. The resultant design, while functionally and technically modern, was perceived to be widely acceptable as an authentic Indian cookware designed for commercially cooking the traditional sunga (bamboo) chicken recipe, as compared to the older design lacking socio-emotional value.

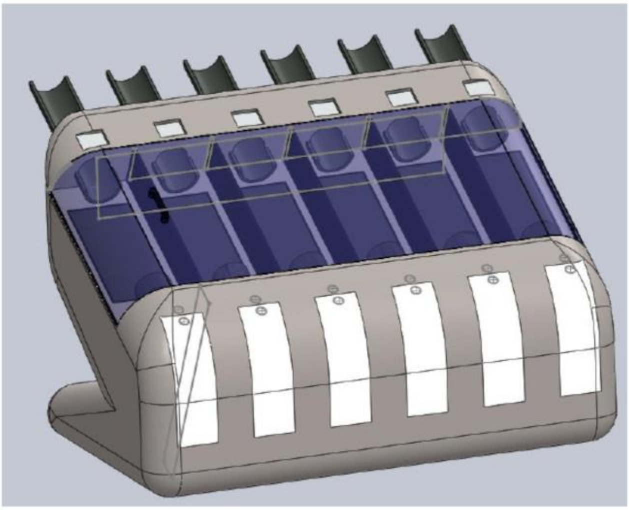 

Figure 2. Left: old industrial design outcome for sunga (bamboo) cookware design
Right: new sunga cookware design considering shared emotional experiences of Indian cooking

7 RESEARCH CONTRIBUTION AND CONCLUSION

The current way of training design students in product design processes vastly focuses on end-user scenarios, mainly involving students studying individual human-object relations. Authors opine that the exposure to multidisciplinary approaches and concepts has the potential of making the emotional product design process and education richer in understanding and knowledge of the objects to be designed. Design students being the future stakeholders of design processes, need to be trained to look at products beyond their physical, functional and end-user oriented aspects, using multidisciplinary approaches and concepts. The concepts like shared emotions, emotional communities, communities of enthusiasm and tools like object biography etc. if introduced to product design students, can widen and deepen their understanding of objects and environment they are expected to design throughout their future career.

For instance, adopting the anthropological tool of 'object biography' can help designers explore and understand the inherent emotional relations between objects and people during various stages of life of objects. This new knowledge about the varying emotional relation with objects can create more and interesting opportunities of emotional design for product designers.

While emotional-product designers consider both functional and emotional aspects of a particular object to be designed, the identification and understanding of emotional communities in the contextually relevant place or timeframe can prove to be of their great help to engender the product designs which evoke shared emotional values and hence potentially get widely accepted and cherished. This was experienced and demonstrated during the sunga cookware design study described in this paper.

Communities of enthusiasm around objects ensure that those objects are kept alive for a longer period of time. A deeper understanding among design researchers and designers, of how certain activities (of making) and objects influence the emergence of enthusiasm and the communities around them, can prove to be very significant in developing knowledge, products and services to support more and newer communities of enthusiasms, hopefully leading to sustainable behaviours.

While a significant part of the contribution of this study comes in the form of the visual illustration of hierarchy of human-object relation, a deeper and elaborate study of the same by design and business researchers can result in the knowledge about various material and non-material factors influencing the transition of this relation and the associated value of making from one state to the higher one. This knowledge in turn can be used by designers and strategists to design and develop products, services and systems targeted at more long-lasting human-object relations in this otherwise throwaway society.

With the mass-produced machine-made products in the market, there is not much scope for integrating the social or shared emotional value in the process of making, except maybe during making of the designs themselves. However, if these products are designed to last long functionally and to be

emotionally and socially engaging throughout the post purchase scenarios, they can indeed enter the hope, love and devotion stages of relation and gain the social and emotional value of their own.
So, there certainly is great scope and potential in understanding more aspects of material culture and applying and integrating the same in design practice and design education.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7-8 SEPTEMBER 2023, ELISAVA UNIVERSITY SCHOOL OF DESIGN AND ENGINEERING, BARCELONA, SPAIN

PRODUCTIVE FAILURE PEDAGOGY IN ENGINEERING MECHANICS

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ABSTRACT
In September 2021, the faculty of Industrial Design Engineering (IDE) introduced a revamped bachelor's programme that emphasizes design for higher complexity, teacher as a coach, and autonomous learning. The programme includes Understanding Product Engineering (UPE), which teaches first-year design students about product embodiment, manufacturing, and mechanics of materials. However, the traditional approach of teaching engineering using direct instructions and problem-based learning was ineffective, as students failed to apply the engineering knowledge in their capstone design projects.
To address this issue and promote autonomous learning, the Productive Failure (PF) pedagogical framework was introduced as the main pedagogical framework in UPE. However, the general approach of the PF pedagogy as described by Kapur, lacked a translation into an effective design of the workshops. To address this, this paper proposes a hands-on model based on constructive alignment, where learning objectives, activities, and assessment are designed side-by-side. This paper presents our didactical model, which was developed in an agile way during the second run of UPE. The hands-on model proposed aids in applying the PF pedagogy in engineering courses and consists of a method to develop workshop assignments and a didactical approach to guide and coach students through the workshop process.

Keywords: Autonomous learning, productive failure, direct instruction, product engineering, engineering mechanics

1 INTRODUCTION
In September 2021, the faculty of Industrial Design Engineering implemented a new bachelor's programme, which includes over 335 first-year students. The curriculum has been updated to reflect changes in the industrial design profession, with courses in technology, organizations, people, data, digital interfaces, and understanding values [1]. The new approach involves semester-long design courses where students apply theory and skills learned in parallel theoretical courses, promoting an autonomous learning attitude. This approach requires a different teaching style, with teachers acting as facilitators rather than instructors.
The Faculty of Industrial Design Engineering previously taught mechanics through direct instruction [2] but found that students were not applying the knowledge in their design projects. To address this, we introduced an autonomous learning approach in the course Understanding Product Engineering (UPE), using the theory of Productive Failure (PF) to promote experiential learning [3-5]. Students solve unguided problems, generating suboptimal or incorrect solutions that are used to provide insights into their lack of knowledge and guide them towards relevant solutions. However, during the first few weeks, students and teachers found it difficult to transition from the ingrained instruction-based learning to a more autonomous learning. We struggled to move from phase one of PF, where students generate and explore multiple representations and solution methods, to phase two, where discoveries are linked to theory [3]. To address this, we changed the workshop structure, stimulating collaboration between students and switching roles between facilitator and instructor. We also created a safe space for the teaching staff, increasing mutual student-teacher respect and trust through dialogue and positive coaching techniques.
Based on our reflections and students' feedback we found out that some workshops worked better than others, but we also concluded that the general approach of the PF pedagogy was lacking a translation into an effective design of the workshops. In hindsight, we learned to design workshops by dissecting

course learning objectives into related concepts, identifying knowledge gaps, and designing exercises around them. During the process we also learned that a safe space to experiment and making mistakes, together with a clear timeframe, is key to successful learning [3].
To help us out in applying PF in a more structured way, we have designed a new didactical model to develop and execute the workshops in the future which considers our previous iterative learnings using design-based research. This didactical model is our next iteration for applying PF pedagogy in our mechanical engineering course. This paper will introduce this didactical model, the Productive Failure Design Cycle, starting with a stepwise model to develop a workshop in six steps, followed by a model to execute the workshop in four phases, following both the exploration and consolidating phases of PF according to Kapur [4,5].

2 APPROACHES

Despite the potential of the PF pedagogy, the general approach described by Kapur [4,5] lacked a translation into an effective design of the workshops. To make it more applicable we used design-based research where we have gone through weekly iterations improving the model with every iteration [6]. The course spans over a 10-week quarter consisting of 8 lectures and workshops to meet the learning objectives of the course. Each week, one or two learning objectives are addressed, followed by a design of the workshop based on the previous year's materials. We used the basic design cycle [7] as a framework to improve our model over the weekly iterations. During the week we noted down the didactical approach from a draft version at the start of the course to a final model nearing the end of the course. Using short design sprints, we weekly improved the didactical approach. We dissected the workshop in more detail every week, reinforcing improvements and filtering out weaknesses which enriched the model in every step to a more solid final model in week 8.

3 RESULTS

To be able to apply the basics of Productive Failure, we have developed a practically applicable didactical model for our course Understanding Product Engineering (UPE) consisting of two parts, designing a PF structured workshop assignment, and designing an implementation model for the workshop.

3.1 Workshop assignment design

The first phase Kapur describes is "Generation and Exploration of RSMs (Representation and Solution Methods)" which has the purpose of developing the right assignment [8,9]. The goal is to find "the sweet spot" of complex problems. Problems that are challenging yet not frustrating, that address prior knowledge and have an affective draw to the students. To develop a workshop and incorporate Productive failure in a constructive aligned [10] educational way, we propose an iterative development cycle starting with a clear Learning Objective (LO), consisting of a core concept to be learned, and a related exam question. The proposed Productive Failure Design Cycle (PFDC) consists out of 6 steps (Figure 1):
Step 1 - Core Concept: The main goal of this first step is to identify the new knowledge or new skill the students need to learn. Derive the "Core Concept" from the defined LO you want to address, and describe the introduced knowledge, principle, or skill that has not been addressed in earlier education, and students do not yet know. If your course is not organized according to the constructive alignment principle [12,13] and Bloom's or SOLO taxonomy [14,15], you can still use defined learning goals or LO's of your course. Every week one or two LO's are addressed.
Step 2 - Exam Question: UPE and most other engineering courses are assessed with a written exam. Translate the LO into an exam question or use a previously used exam question. An exam question where students must calculate an outcome using formulas, to support design engineering decisions, is helpful.
Step 3 - Real Application: Think of a real-world engineering application of the knowledge or skill. In what situation would an engineer apply it. This helps both teacher and student to have a realistic context. We brought the real products and identified real designer's situations, like ordering pizza or beers at the student café, assembly of a bicycle bell, breaking or bending of a carabiner, Bill of Materials of a ballpoint pen, and so forth.

Step 4 - Problem: Define the problem the student must solve. To iteratively explore and deepen the problem and get to the root problem, we use the technique of asking WHY three to five times. It helps to get to the core of the problem.
Step 5 - Solution: Now take the problem and think of wrong solutions they can come up with, or which you came across when you were taught this concept. Think of the mistakes students will make because they do not know yet how to tackle it or make false assumptions due to the lack of knowledge. Make a list of what could possibly go wrong when people miss important knowledge or skills.
Step 6 - Redefine: Take the redefined problem and redesign the problem as a question: an assignment as a narrative with dialogue. It is important to check if the assignment can only be solved when students have access to the knowledge of the core concept, but where students can still try out things and are under the illusion, they can solve the problem using prior knowledge. Check if the assignment still addresses the core concept and has an affective draw of the problem scenario [16]. If not, redo the previous steps again.

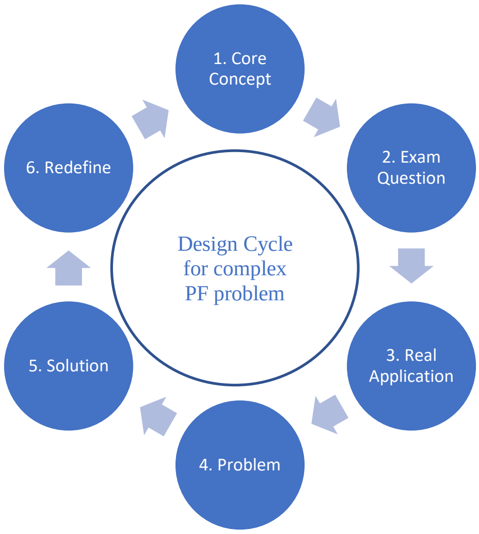

Figure 1. The proposed Productive Failure Design Cycle to come to PF based workshop assignment

3.2 Workshop implementation design

The workshop uses a time-guided set of workshop slides that introduce students to the challenging problem of the week, followed by a recorded instruction video and a problem they can solve using their new knowledge. Figure 2 shows some excerpts of the workshop slides.

Figure 2. Excerpts of a workshop: starting the workshop with a challenging problem students cannot solve with prior knowledge (top left), followed by a video-instruction explaining the concept (top right), after which students can work on a similar problem they can solve (bottom left) with its solution (bottom right)

To create an engaging and effective workshop, we took a meticulous approach to its design. Our iterative process led us to several key realizations that helped us “design the social surround for creating a safe space to explore” [16]. We discovered that using familiar vocabulary, such as the designer's language, created a comfortable and inclusive environment for both coach and student.
Drawing on this insight, we implemented the "basic design cycle" [6] as our process steps for the workshop, where, for instance, we rephrased “generation and exploration phase” to "ideation phase" that builds on the students' existing brainstorming skills. As design students they are used to developing multiple representations and solution methods (RSMs) and come to design solutions. In addition, our teachers also understood their role of managing the classroom in problem solving, instead of giving instructions on the objectives to learn.
Finally, we renamed the "Consolidation phase" as "Selecting and Trying" to reflect the design process more accurately. This change was embraced by both teachers and students, who found it easier to connect with the design perspective and bring their ideas to fruition. By thoughtfully redesigning the workshop, we were able to create a more engaging and empowering experience for all involved.
With 335 students in the course, we have divided the students into 14 studios, consisting of approximately 25 students coached by one teacher or teaching assistant. To facilitate a collaborative and engaging learning experience, each studio is equipped with a large screen that displays the workshop's materials. This technology allows students to easily follow along with the lesson and stay engaged throughout. Students are seated at tables with five to six peers creating an atmosphere of teamwork (Figure 3). The tables are outfitted with materials to participate fully in the workshop, including computers, whiteboards, and a wide range of materials like paper, markers, callipers, weighing scales, screwdrivers, and more.

Figure 3. Collaborative learning solving engineering problems using the whiteboard as a central tool

The workshop is divided in four phases as pictured in Figure 4 and explained underneath:
Phase 1 - Prepare: During the preparation students are introduced to a formative assessment in the form of a group quiz. The questions asked in the quiz give a view on possible exam questions or parts of it. The questions reflect retained knowledge from secondary school and knowledge from previous week(s). The quiz is time-bound, and answers are given after the quiz. The quiz activates foreknowledge and gives the students a sense of confidence. It also marks the start of the workshop and engages them in the day’s workshop.
Phase 2 – Ideation: During the ideation phase students are introduced to the problem, and brainstorm about differing solution strategies. After 10 minutes three possible strategies are explored to come to a solution to the problem introduced. The solutions are explored in depth, preferably in duos or as a group. Exception can be made to do it individually. The students make use of the whiteboard to make them explain their strategy to each other and engage other students in the collaborative thought process. At the end of this phase student groups present each other’s work to the rest of the students within the studio and discuss their findings, hurdles, and success or failure.

Phase 3 - Prototype: During the prototyping phase a video lecture is shown where students get the direct instruction of the knowledge needed to come to a correct solution for the problem presented. We make use of pre-recorded videos to have an equal explanation and instruction of the specific week's knowledge needed. We leave some autonomy to the studio's coach to enrich the explanations with personal experience and examples. After the instruction the student groups are exposed to a sort-alike problem in a new context and solve it individually to make the knowledge their own and confront the individual student to their own knowledge gaps.
Phase 4 – Evaluation: To close the workshop the students are presented with the correct worked-out answer to the second problem. In the studio the answer is discussed, and key-finding are drawn as a group. Students are asked to jot down their main important findings on their own personal note (cheat sheet), which they can bring to the final exam.
To have students exercise at home, we have developed several online questions using Möbius STEM software [17].

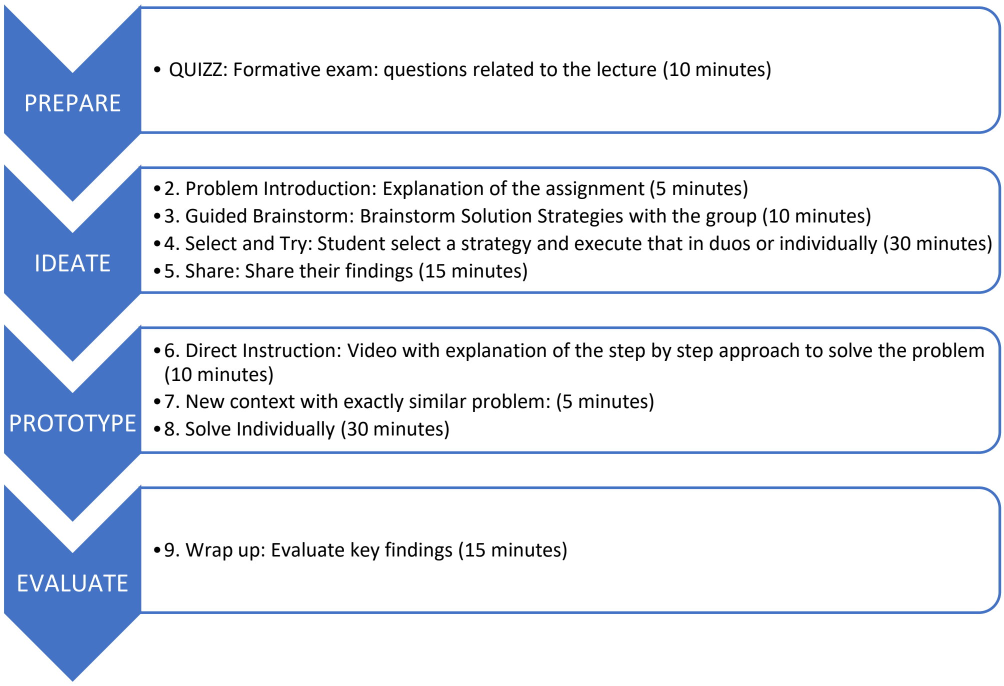

Figure 4. Workshop design: flow over one afternoon starting at 13:45 and ending at 17:30

4 DISCUSSION AND CONCLUSION

In 2021, we began implementing Productive Failure as our didactic framework for creating instructional materials and workshops. We quickly realized the need for a structured approach to guide us through the development process. During the most recent iteration of the course, our focus was on creating the Productive Failure Design Cycle. The objective was to design engaging and effective workshops and instructions not only for this particular course but also for future courses.
To achieve this, we adopted a weekly iterative design cycle consisting of six steps: core concept, exam question, real application, problem, solution, and redefine. Additionally, we established a four-phase didactic approach for workshop execution consisting of the following phases: prepare, ideate, prototype, and evaluate.
Collaborative brainstorming sessions involving the content expert of the week and some studio coaches proved to be the most effective method for developing workshops using the defined six steps. However, progressing from step 1 (core concept) to step 4 (a realistic assignment with productive failure) presented some challenges. This process requires a facilitator who guides the team and asks the right questions to refine and create a suitable assignment using the learning objectives as a starting point. Once the assignment was defined and aligned with the learning objectives for the week, describing the workshop became a straightforward task.
Based on our initial implementation in 2021, we recognized the importance of time management for the effectiveness of the workshops. To address this, we incorporated timers for each activity. Additionally,

since the instructions varied across different studios, we introduced weekly video instructions during phase 2 of the workshop to reduce reliance on individual coaches.

The time-paced approach and instructional videos helped the coach team stay on track with the content and made the workshops less dependent on specific studio arrangements. Consequently, there were fewer discussions with students regarding studio allocation. In this new context, the role of the studio coach shifted towards facilitation rather than traditional teaching or expertise. While some coaches initially perceived this change as a demotion, we realized that the coach's alignment with the PF pedagogy mattered more than their specific expertise. In fact, less-knowledgeable coaches, such as teaching assistants, could effectively guide the students.

Although we observed a slight improvement in the pass rates, it is essential to conduct further quantitative research to determine whether this can be attributed to the pedagogical framework. Additionally, qualitative research is necessary to explore the experiences of both students and teachers. We must also investigate knowledge retention in our UPE course, considering the positive effects of PF demonstrated in Kapur's research.

To evaluate the practicality of this method in different contexts, we successfully facilitated the PFDC in one new developed master course ID5422 Repair!. The next step is to document the design cycle in such a way that others can apply it in their own settings without our direct facilitation. As of now, the limited available data prevents us from drawing definitive conclusions regarding the effectiveness of the framework.

ACKNOWLEDGEMENT

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LINKING A LAB ON PROTOTYPING FOR ENGINEERING STUDENTS WITH ITS "DIGITAL LEARNING ENVIRONMENT TWIN"

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ABSTRACT
The restricted timeslots for the use of labs and the availability of resources are often the cause of delayed student projects. This paper describes the transition of an existing lab on prototyping for engineering students from the analogue world into a digitized learning environment that can be used 24/7. This includes all aspects starting from general safety instructions and ending with detailed information and examples on how to use the machinery. Through this transition, the students gain more flexibility in their planning and work in a more agile manner. In addition, with the digitization of the "creative prototyping" lab, the quality of instructions given to the students and the documentation have changed in a positive way. The framework for the digital learning environment twin is provided through the Moodle platform. It is complemented by the e-portfolio software Mahara for the project documentation needed for the test course on project-based product design used to evaluate its digitization. The "digital learning environment twin" combined with Mahara provides a fully digital assessment of the course and provides a positive experience for students and lecturers.

Keywords: Product design, prototyping, digital twin, digital lab, Moodle

1 INTRODUCTION
The transition from an analogue to a digital learning experience is more complex in certain fields of study (e.g., engineering) than in others. This paper deals with the digitization of a laboratory for creative prototyping used in engineering education at the University of Applied Sciences Ansbach, Germany. The lab is used in a course on project management where students are required to develop and build a wooden product from the idea to the prototype.
In recent years, it has become apparent that the manufacture of a prototype is time-critical in many cases and contingent upon the availability of staff, machine capacity, and time allocated for working in the lab. The solution we developed to these problems involves a digital twin of the "creative prototyping" lab. It is available around the clock to students, thus reducing the need to be on-site and keeping fixed deadlines to a minimum. The digital twin allows for greater project flexibility, enabling professors and lab staff to provide higher-quality and individualized support for students (who in turn improve their tool and machinery skills) [1]. In this paper, we describe the changes that are needed to digitize the lab and link it to the analogue world and evaluate the suitability of our framework for engineering education. First, we present the steps involved in digitizing the lab. This is followed by a section on the challenges posed by the analogue-to-digital conversion. The paper concludes with some feedback from the staff, the lab's incorporation into the project management course, and a discussion on whether the digital lab might increase the agility of engineering education.

2 THE METHODOLOGICAL APPROACH TO THE DIGITIZATION OF THE LAB
The digitization of the lab takes place in several steps and on several levels. The main framework comprises a project management course on the learning platform Moodle, a widely known and well-established environment that enables the individual elements needed for lab usage and the course itself to be connected and digitized.

The digital learning environment twin of the creative prototyping lab can be separated into two principal sections. The first maps the product development cycle of the product management course from the initial idea to the production of the prototype (Figure 1). The second maps the lab itself with all the machines, tools, and documents that are needed as well as the safety training.

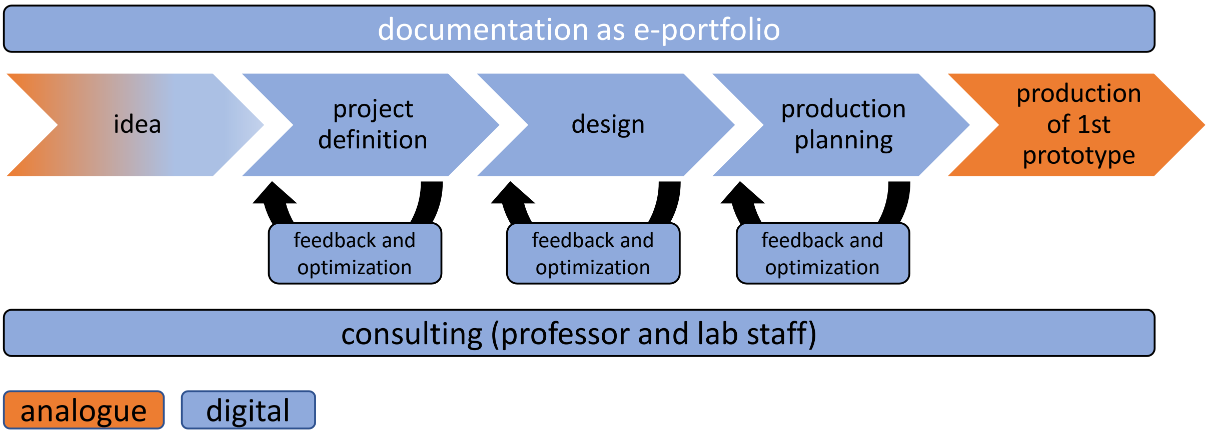

Figure 1. Flowchart of the workflow during the course "project management"

The course on project-based product design, which was used to test our prototype's digitization and usability during the summer semester of 2022, is a mandatory course in the sustainable engineering bachelor's programme at the university of applied sciences. We merged product design and project management and designed a course that satisfies the demand for product design education and provides a satisfying initial experience of project management for the students [2]. The students are required to plan, design, and build a prototype for a wooden product (for children aged 3+ or teenagers up to 16 years) [3+4]. They are free to decide on the target group for their projects. Currently, the course is conducted and coordinated face-to-face within the creative prototyping lab during scheduled hours. The procedure is therefore analogue and non-agile.
The individual intermediate steps of the course have been digitized, and progress is subject to feedback loops and checks by the professor and staff. The students have to complete each step of the product development cycle before advancing. The completion of each step must be synchronized with the project schedule of the students, which cultivates their time management skills. Their work is documented throughout the course in an e-portfolio, and their completed (digitized) project [5] is submitted using the portfolio software system Mahara [6]. Only the manufacturing and the physical prototype of the product idea take place/exist in the analogue world.

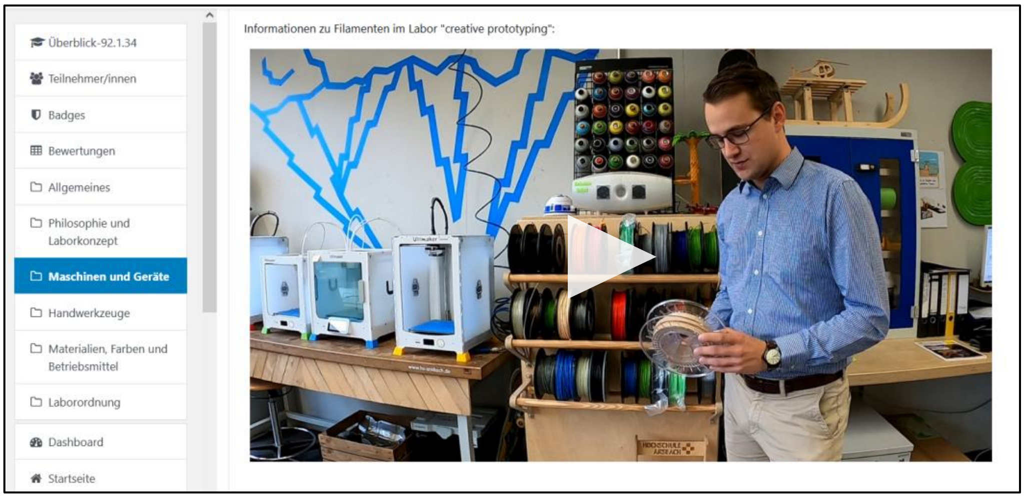

Figure 2. Video frame of a staff member describing the attributes of filament spools for 3D printers using the fused deposition modelling technology embedded in Moodle

The second part of the Moodle course maps the lab digitally. The process begins with mandatory general safety instructions, including the machine manual and specific safety data sheets. This section of the course is divided into subgroups: an overview, operating instructions, safety instructions, safety data sheets for the different machine types (e.g., 3D printer, laser cutter, and milling machine), and links to the required software. The level of detail increases the deeper the students go into each topic. For each machine, a short data sheet with the technical data, the most important safety instructions, and possible applications can be found at the first level. The next level offers access to video material (Figure 2) that maps all the instructions for the individual machines and devices, independent of the time of day or the lab staff's consultation hours.

The general safety instructions for the creative prototyping lab and the instructions for the individual machines and devices (including hand tools such as saws, pliers, and knives) were previously carried out in person, noted on a sheet, and filed in a folder for each student or small groups of students. This was a very important but time-consuming task. As part of the digitization, we mapped the general safety instructions as an e-learning unit for which the students receive a certificate upon completion. This is then digitally archived, so the previous paper-based form of documentation has been supplanted. The safety instructions for the individual machines and devices are carried out through e-learning and a final test, and the students receive a certificate of completion. A result of 100% must be achieved in all safety instruction tests. Figure 3 shows a screenshot of the general safety instructions test.

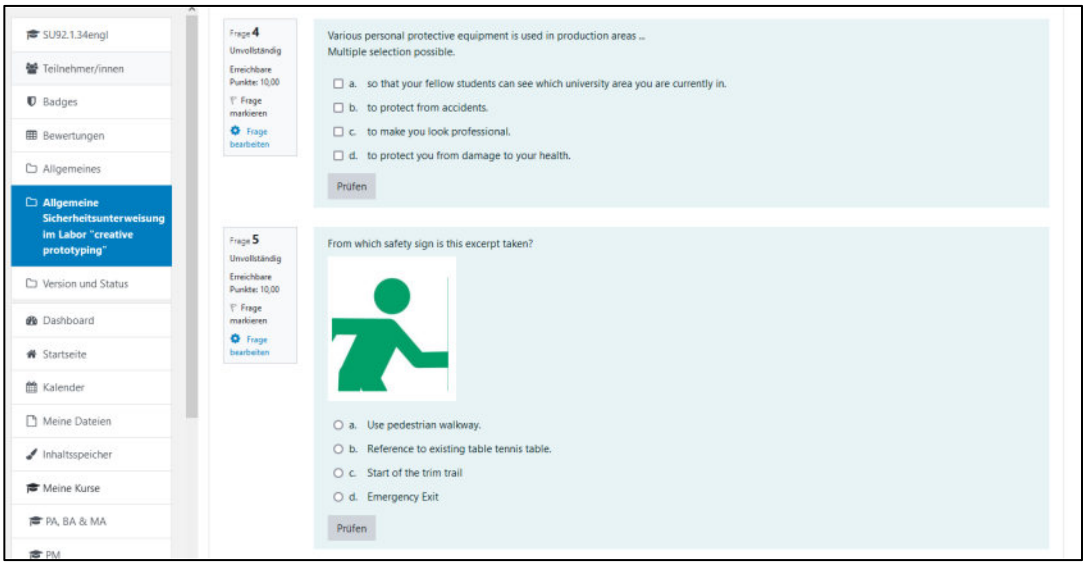

Figure 3. Part of the test on general safety instructions

The digital approach to the safety instructions part of the course is superior to the previous analogue route in virtually all respects. The flexibility it affords (as with the machine instructions) in terms of time is the biggest advantage. The understanding of hazards and processes is also improved through the combination of self-study and a mandatory final test. The digitized lab is rounded off by an appointment calendar (on Moodle) that can be used to book machines and consultations with the professor or the lab staff, during which general questions or issues raised during feedback loops can then be addressed.

3 THE CHALLENGE OF TRANSFERRING THE LAB TO THE DIGITAL WORLD

Various difficulties and obstacles were encountered during the implementation of the project. First and foremost, the professor and staff had to invest a great deal of time in preparing it. The digitization of a lab that ordinarily functions solely in the analogue world necessitated discrete solutions for a multitude of small problems, and the effort required to produce the videos, images, and audio recordings for synchronization with Moodle was substantial. The time involved far exceeded the time needed to prepare an analogue course and indeed the length of the semester itself. However, the effort was a one-time effort, and subsequent maintenance and updates to the course will be less time-consuming than the analogue version.

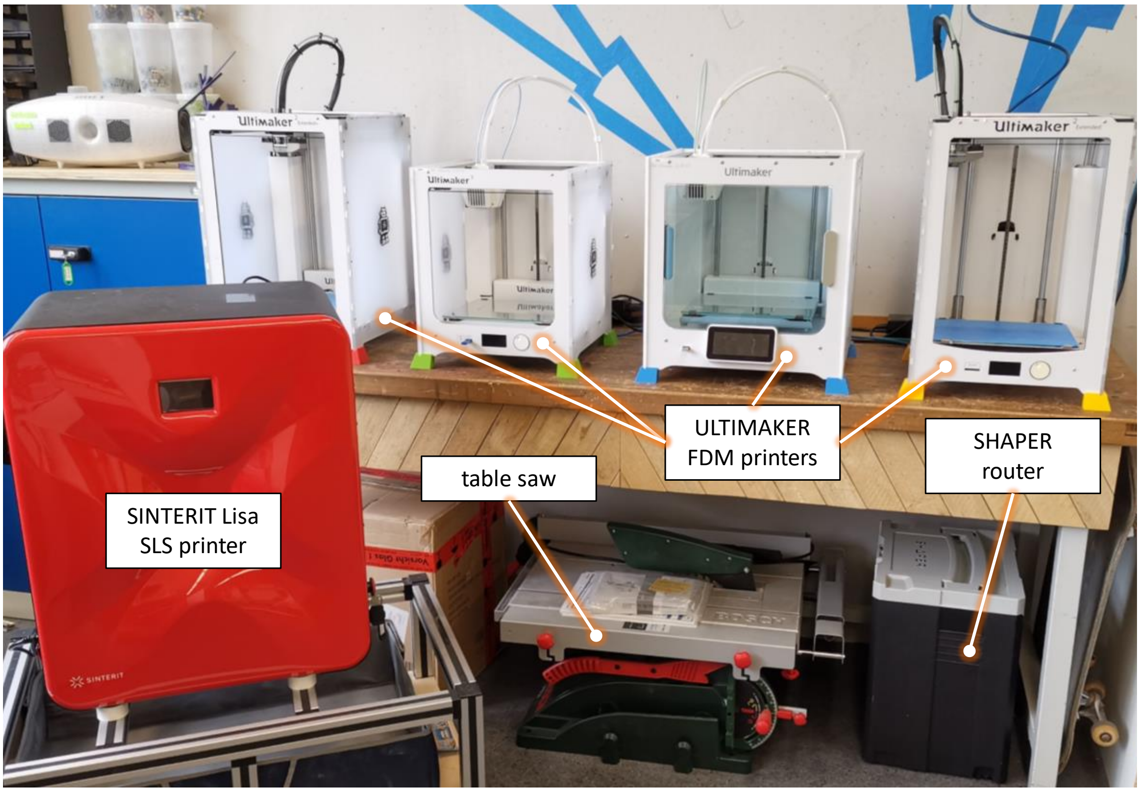

Figure 4. Resources and machinery in the "creative prototyping" lab (3D printing corner)

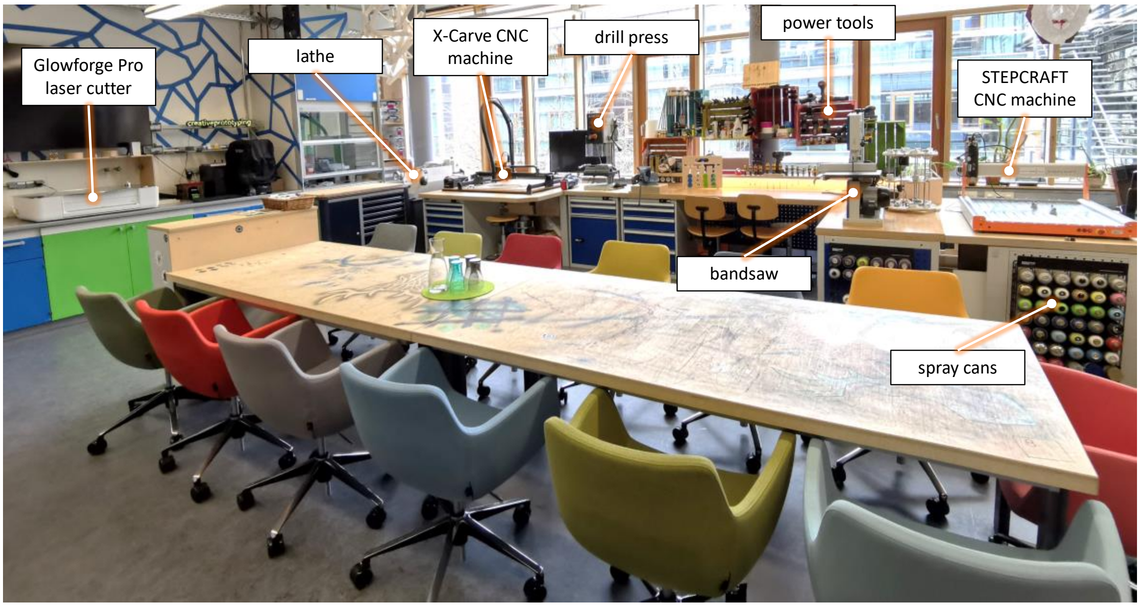

Figure 5. Resources and machinery in the "creative prototyping" lab (view from right corner)

Another problem was presented by the different interfaces between the lab machines and devices (Figures 4 and 5). Since the latter tend to be designed for the hobby sector and enthusiasts, and there are no common interfaces for devices and machinery for industrial use, direct communication is virtually possible. Though every fabrication machine works with g-code-based controls, and some come with browser-based software, each type of device had to be prepared separately, and this applies even when a 3D printer is changed in favour of another model from the same manufacturer. Acquiring a uniform system to manage, control, and supply all the devices with data or devices with industry-standard interfaces was not an option, for financial reasons.

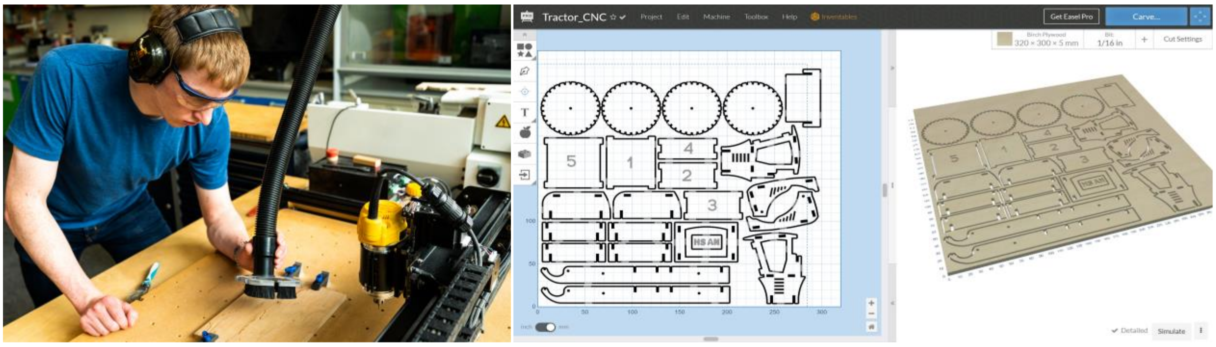

Figure 6. Student working with the CNC carving machine (left) and view of the browser-based software for the milling machine (right)

To solve these issues, we first created a network to control the 3D printers and the laser cutter. These devices have either built-in Wi-Fi capabilities (e.g., the Glowforge laser cutter) or can be connected using an ethernet interface (e.g., the series 3 Ultimaker 3D printers and later). Students working in the lab can connect to the network and access the devices virtually. The browser-based milling machine software (Figure 6) [7] and the laser cutter can be prepared independently of location; only the final manufacturing has to be done in person. The software is linked within the Moodle course and is readily accessible. The course is supplemented with links to online CAD [8] and slicing software for the FDM 3D printers, which gives the students even more flexibility. Unfortunately, these browser-based tools cannot be embedded as plugins into Moodle. The current version of the digital twin of the creative prototyping lab jumps from digital solutions within the infrastructure of the lab and the university to external infrastructure. This will be the subject of further research.

Similarly, external access to the devices or the lab itself is not entirely straightforward. Although an internal lab network exists, it is not connected to the public Internet and cannot be accessed remotely (for security reasons). A completely automated and globally accessible solution is therefore necessary. Unfortunately, this is not financially feasible for the university; what is more, since the solution would have to be bespoke, time is a limiting factor. At present, the submission feature of the Moodle platform is being used as a compromise. After the student submits their doublechecked production data, a member of staff transfers them to the lab's ecosystem and conducts a last check before the prototype parts are manufactured. A centralized means of exchanging and storing production data from outside the lab's ecosystem that bypasses the need for manual work on the part of the staff is in progress.

4 FEEDBACK AND CONCLUSIONS

The feedback given by the students on the 2022 summer semester led to the conclusion that access to the lab (e.g., in terms of timeslots) and the overall experience of it had to be improved upon. Following the next round of the course on project-based product design (to take place this year), the evaluation of the changes made to the creative prototyping lab and the students' interaction with this new digital learning environment twin will be evaluated. The evaluation will include an assessment of the project documentation using the e-portfolio software Mahara and a section for the presentation of new ideas. Based on the results of the evaluation, changes to the digital learning environment twin and the overall process will be carried out iteratively over each new semester. The course lecturers have observed a decreased and more flexible workload because the students do not have to consult with them in temporally constraining conditions. The high initial investment of time and work in setting up the digital learning environment twin has already begun to pay off.

In conclusion, the digitization of the creative prototyping lab and its use in teaching has proven to be a viable concept. For instance, the increased understanding of hazards and processes within the lab has improved through the combination of self-study and mandatory testing. Our concept can, however, be improved upon. Without the consistent use of digital offerings, the course will fall back into traditional – that is, more analogue – patterns. Thus, all those involved must maintain discipline. We intend to transform the creative prototyping lab into a digitized and open-access production space for students from all faculties; for example, it will be extended and equipped with technology to design, build, and program electronic devices and systems. The lessons learnt from creating a digital learning environment twin and the different rounds of evaluation will provide the basis of a production space that offers new levels of usability and 24/7 access for all.

ACKNOWLEDGEMENTS

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7-8 SEPTEMBER 2023, ELISAVA UNIVERSITY SCHOOL OF DESIGN AND ENGINEERING, BARCELONA, SPAIN

DESIGN FOR EXTENDED REALITY (DFXR) – EXPLORING ENGINEERING AND PRODUCT DESIGN EDUCATION IN XR

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ABSTRACT
With the rapid development and increasing utilisation of eXtended Reality (XR), sustainability considerations have become an important factor in the design process. Despite the many advantages of XR, existing studies covering design education research show a fragmented early phase application use primarily focusing on local use-cases rather than global interconnected alternatives. While many universities are developing their digital capabilities using XR for various educational purposes, few examples exist of interceded activities using multiple variations of XR (i.e., VR, AR, or MR). Establishing a more interconnected set of use-cases is important to fully realise the potential of this technology. Past methodological considerations have been presented through guided design steps when working with elements of XR. However, to position early attempts to work on design imperatives using XR this paper presents a literature review and content analysis to examine the current state of design principles for XR. By utilizing the Design Society's knowledge repository, it employs a categorization process and charts valuable insights of existing XR pedagogical practices. Ultimately, this paper highlights the importance of considering sustainability in digitally enabled prototyping steps and practices using XR and its relevance for the E&PDE community. It also emphasises the need for more research and attention on how XR is practised and how it can be used to advance sustainability efforts.

Keywords: Design, extended reality, XR, augmented reality, AR, virtual reality, VR, mixed reality, MR

1 INTRODUCTION
Design for extended reality (XR) refers to the creation of digital experiences that blend the physical and virtual worlds. XR includes virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies that allow users to interact with digital content in real-world environments. XR has the potential to revolutionise design education, particularly in the context of sustainability. With the use of XR technology, design educators can create immersive and interactive experiences that allow students to explore sustainable design principles, materials, and techniques. In this way, XR technology can promote a deeper understanding of sustainability and help students develop skills and knowledge to design sustainable solutions that meet the UN's sustainability goals [1]. Designing for XR involves creating immersive experiences integrating the user's surroundings and providing a sense of presence and interactivity that can accelerate the product development cycle [2]. The design process of XR is a multidisciplinary approach that combines the principles of architecture, spatial design, interaction design, visual design, audio design, and user experience design [3].
XR design typically involves the following key elements:

1. Spatial design: XR is inherently spatial, designing experiences require careful consideration of physical space and how the virtual content is situated within it. Designers must consider the user's movement and ensure that the experience remains comfortable and safe in the virtual environment, this includes the placement of objects, scale, and movement [4].
2. Interaction design: XR experiences require intuitive interaction mechanisms that enable users to interact with digital content in natural and intuitive ways. This may involve using gestures, voice commands, or physical objects as input [5]

3. Audio design: Sound plays a crucial role in XR experiences, helping to create a sense of presence and immersiveness. Audio design for XR may involve creating 3D soundscapes that change as the user moves through the environment [6].
4. User experience design: XR experiences require a seamless user experience that is easy to navigate and understand. User experience design in XR requires designers to create interfaces that are easy to use in a 3D environment and ensure that the experience is accessible to users with different levels of experience and abilities [7].
5. Visual design: XR experiences require high-quality visuals that can immerse users in the digital environment by creating high-quality 3D models, textures, and lighting that are optimised for XR displays. Designers should balance visual fidelity with the need for efficient rendering, user comfort and consider the colour temperature, contrast, and saturation when designing interfaces [8].

XR design involves creating immersive experiences that seamlessly blend physical and virtual environments to create new forms of interaction and engagement, incorporating spatial design, interaction design, visual design, audio design, and user experience design principles. XR user interfaces used in engineering design have frequently reported deficiencies that create interruptions or gaps in the user's workflow [9]. Despite the potential benefits of using XR in the design process, there are still several obstacles that must be addressed in order to ensure an efficient and effective design process [10]. To minimise errors and enhance the quality of XR design, this paper introduces the acronym DfXR, which stands for Design for XR. By using this acronym, the paper aims to promote and standardise the use of this term within the XR design community. DfXR should be considered as crucial as other well-established methodologies such as Design for Manufacturing (DfM) for ensuring efficiency, speed, and high production rates. The design process must be structured to produce efficient outputs, as research suggests that more than 70% of manufacturing costs result from design choices made during the early design phases, including material selection and manufacturing methods [11, 12]. Therefore, it is imperative for companies to focus on improving their design processes to reduce costs and enhance the quality of their products. By incorporating DfXR principles, designers and ultimately companies can minimise errors and ensure that their XR designs meet the requirements of users and stakeholders [2]. Therefore, the dual purpose of this paper is to explore; i) the relevance for XR for engineering and design education, and ii) to find out key considerations that are necessary for a successful DfXR approach.

2 BACKGROUNDS

Design is a complex, high-order cognitive activity that relates to multiple cognitive processes such as visual processing and reasoning, decision-making, emotions and problem solving [13]. By adopting and preparing for an integration of XR [14], a crucial step in the design process becomes to establish authenticity and realism. Realism in XR applications refers to the degree to which the virtual environment mimics the physical world, and this affects the user's sense of presence and immersion in the environment. Achieving high levels of realism in XR applications can enhance the user experience, increase the user's sense of presence in the virtual environment, and reduce cybersickness [15]. When designing an XR application, it is essential to consider both input and output devices, regardless of the hardware being used. Input devices refer to the mechanisms through which users interact with the virtual environment, such as controllers, hand gestures, or voice commands, while output devices refer to the mechanisms that deliver visual and auditory feedback to the user. Designers must consider the type and compatibility of input and output devices when designing XR applications to ensure that they are safe, accessible and easy to use [16]. The inclusiveness of XR has become increasingly apparent in recent years with the attempt to merge augmented reality’s benefit of immersiveness applied to VR [15] where we today see many XR devices, with integrated features like hand tracking as a built-in input option, e.g., HoloLens 2. This underlines that spatial design is reaching new heights with refinements to the optical hand and finger tracking where natural interaction schemes mimic how we operate in the real world [17]. This technology is the only option that offers direct interactions with the hologram, without any additional devices or markers and therefore brings no interruption to the classic workflow [9]. Haptics play an important role for visual interactive representation resulting in attempts to use ultrasonic sound and vibrations to be applied for haptic feedback [18]. By automating the detection process, designers can focus on creating immersive experiences without worrying about technical constraints. Several studies have demonstrated the effectiveness of using AI and Machine Learning (ML) algorithms in the design process [19, 20]. The strength of an AI-based approach for predicting e.g., user preferences in immersive environments opens for deep learning algorithms to analyse a broaden pattern of user behaviour.

3 RELEVANCE OF DFXR TO THE FUTURE OF DESIGN EDUCATION

Known as Metaverse, a virtual reality space allowing people and digital objects to interact in a shared environment presents an opening for testbed activities as AI, ML algorithms and deep learning architectures, which are expected to play an important role in development of new learning environments [20]. The successful implementation of XR in higher education requires the consideration of multiple areas and stakeholders. Still, little focus has been given to study the product design education can process and capture XR without presenting specific technology features or case experiences [21]. XR has the potential to enhance teaching and learning by breaking down the boundaries of traditional classrooms, establishing playful gamification scenarios [11]. Facing new types of immersive environments for presenting and delivering instructional content [22], XR enables unique learning experiences, and develops communities of inquiry and practice [10, 23]. An integration of emerging technologies such as XR provides opportunities for increased understanding in design and engineering disciplines, while not jeopardising cognitive loads. It is crucial for educators, designers, and technology experts to collaborate and prototype iterative ways for co-designing [24], in the potential design of a XR-enhanced gamified learning experience [10]. Therefore, design considerations should match the needs and goals of learners, the appropriate use of technology, and the alignment of XR activities with learning outcomes [25]. By doing so, higher education institutions can optimise the use of XR transforming teaching and learning embedding interdisciplinarity by incorporating AI and ML as part of a more immersive design education.

4 METHODOLOGIES

This is a position paper that draws on an extensive literature review on the application of design principles for XR and potential implications on existing practices. By looking at trends and potential gaps in current research and providing insights into effective XR pedagogical practices. The Design Society's rich knowledge repository was analysed using both descriptive and content analysis. Tracing relevant past experiences, identifying relevant studies based on the inclusion criteria and keywords 'extended+reality', and source 'paper'. Papers were thereafter categorised based on content screening with inspiration from open coding [26]. Due to page limitation the E&PDE* reference list and the categorising process have been drastically shortened.

5 FINDINGS

To elicit key characteristics of selected papers, an initial abstract review was conducted to validate the relevance of the papers and limiting the total of 220 papers initially found, to 56 out of 1619 in the E&PDE series. The last decade presented a short list of 46 papers, which after screening went down to 25 papers that all bring attention to XR in the last decade within the E&PDE community. Notably, only one paper from 2008 showed any initial relevance. Descriptions that could be attached to the different papers showed multiple aspects of XR (e.g., immersive teaching, design tool, STEM skills, spatial abilities, frameworks, learning modality, role). The papers are mainly exploratory approaching functionalities in different use-case scenarios and in combination with other aspects of design e.g., drawing to overcome transferability and communication, scalability and safety in work practices. The papers also highlight the necessity for new digitalized skills, including XR from a user-centric perspective. The collection of papers provides evidence of good practices and successes of immersive XR experiences rather than solely focusing on the design principles behind these explorations.

Table 1. E&PDE series, last decade on Extended Reality*

Year(s): 10	Number after keyword search: 46	Number based on relevance and scope: 25
2022	8	8, immersive teaching, gamification, onboarding, co-design, additive manufacturing, design tool, learning modality
2021	12 (-6 after screening)	6, STEM skills, spatial abilities, remote VR prototyping,

		creativity using VR tools, XR platform
2020	2	2, VR in design education, educational role, multimodal drawing framework
2019	7 (-4 a.s.)	3, VR as teaching tool, lab, challenges
2018	4 (-3 a.s.)	1, AR familiarity
2017	4 (-3 a.s.)	1, new design paradigm
2016	3 (-3 a.s.)	0
2015	1	1, industrial design AR
2014	4 (-2 a.s.)	2, emotion assessment, educational role
2013	1	1, evaluation, early design concepts

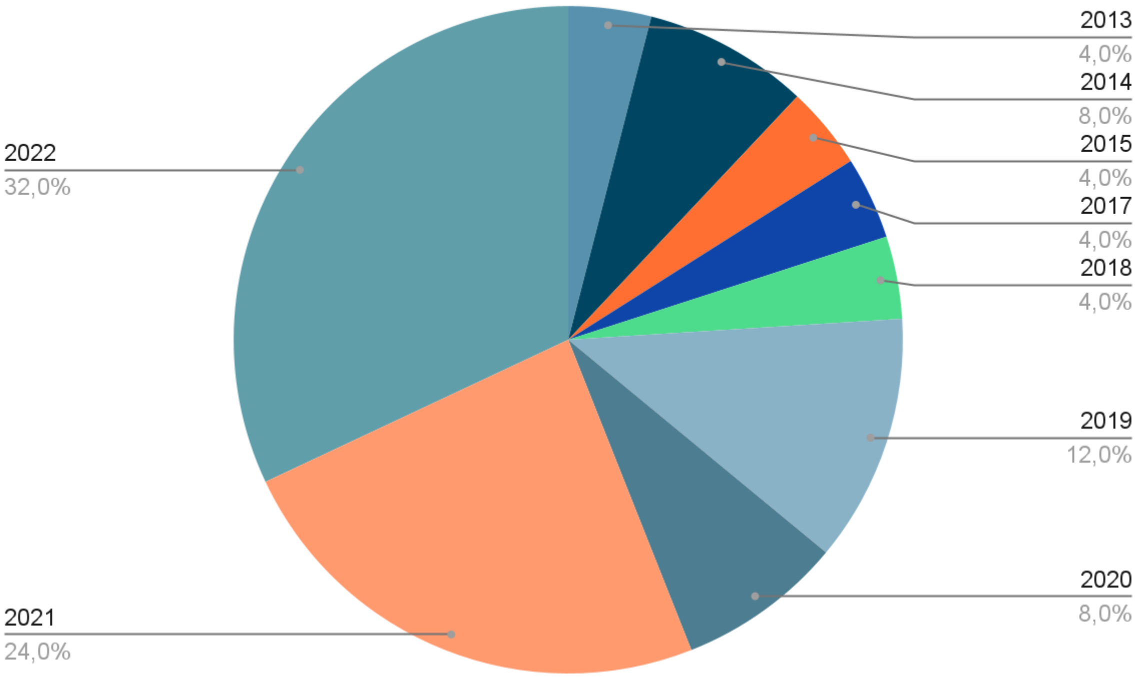

Figure 1. Annual distribution of XR 2013-2022

6 DISCUSSIONS

XR is gaining significant momentum and attracting growing interest within the engineering and product design education community. Its research scope is expanding exponentially, reflecting the increasing recognition of its potential. As a theme is emerging there is still little attention shared on how to develop XR using robust and sustainable design principles. Indications are similar across a multitude of other places, e.g., society, business, healthcare, research and education. This poses implications that necessitate a deeper consideration of how to design sustainable efforts for the long-term benefit of XR. Additionally, this paper also presents the relevance and the essential factors for effectively implementing a DfXR approach. The ratio of produced material covering XR for design education is rapidly increasing, presenting the advantages of cross-platform interlinkage [9], establishing new ways of critical learning [21]. The need for a seamless design interaction put emphasis on an iterative prototyping process where digital alterations enrich materialised cognitions [22]. XR applications, particularly those focused on VR for engineering design, commonly present gaps in the user's workflow, such as data-gaps [9]. Once modifications are made to the data, the complexity of data conversion is causing problems, the second gap relates to the potential of a hardware-gap, where most modern immersive devices, such as head-mounted displays and hand-held controllers, require the user to wear a headset or visit a specific area to switch from classical to immersive workflows. What is referred to the Open XR runtime standards are currently extending the possibilities between hardware and software interoperability, which can potentially increase XR sustainability by making the technology more accessible. By identifying and exploring remote design processes, collaborations that utilise a mix of technological platforms are looked at and how interaction of XR practices and processes affect aspects like internationalisation and interconnectedness. With a growing number of students, professional workers and companies utilising new remote-working norms, a better understanding is needed to support distributed and sustained XR collaboration. The study proposes features for DfXR by building upon past immersive XR user experiences [6, 10, 22, 24]. To address the complexity of the design approach and its impact on virtual product development, the integration of AI and ML algorithms can automatically detect essential constraints [18, 19]. DfXR is a design approach that seeks to optimise user experience by involving the creation of virtual products that are immersive, interactive, and responsive to user input. However, DfXR is often challenging due to the complexity of creating immersive experiences that meet the user's expectations. To address this challenge, AI and ML algorithms have made their way into the design process. Using algorithms essential constraints can be detected in immersive design features, such as motion tracking, object interaction, and visual fidelity. Integrating AI and ML algorithms into the design process can help overcome the deficiencies in immersive extensions of key design features for DfXR, aimed at enhancing immersive user experiences. These algorithms can automatically detect essential constraints, allowing designers to focus on creating immersive experiences.

7 CONCLUSIONS

This paper provides overall design guidance and highlight the community's increasing interest in XR. The rapid growth of XR and the interest for XR design principles are providing space for greater solutions to be made. This research presents that the design education discipline has shown an escalated interest in how to use and develop meaningful learnings with XR. To pursue such design efforts XR applications need to consider various criteria, including realism, spatial design, input and output devices, cognitive and emotional factors, and privacy and security. These design criteria are essential in ensuring that XR applications provide an immersive, engaging, and accessible user experience. Still, additional research is needed to further investigate effects and implications of design approaches of XR. Understanding the sustained impact of these design practices can contribute to the development of more effective and responsible XR experiences that transcend disciplinary boundaries and extend across diverse domains.

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IMPLEMENTATION OF A VIRTUAL LEARNING ENVIRONMENT FOR IMMERSIVE TEACHING OF THE OPERATION OF HIGH-RISK EQUIPMENT IN ARCHITECTURE AND INDUSTRIAL DESIGN WORKSHOPS

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ABSTRACT
Learning the use of machinery for the transformation of materials, such as wood and metal, continues to be an important part of the architecture and industrial design students training, due to the manufacture of models and prototypes. The teaching-learning process of this type of equipment has always been face-to-face, with minimal interaction and attention from the students, to learn the sequence of operation and security measures.
On the other hand, and due to the return to 100% face-to-face classes for more than a year (due to the drop in COVID 19 infections), the development and implementation of learning activities with the support of virtual reality technologies is increasingly used in the training of design and engineering students at a professional level. It is for this reason that a virtual environment was developed to support the learning process of the most dangerous machines for the transformation of wood and metal. This environment, installed in the VR Zone at Tecnologico de Monterrey, Campus Queretaro, Mexico, has allowed greater immersion, interaction, and feedback in learning the aspects of use and safety of the mentioned machines. The objective of this virtual environment is to be an effective complement to face-to-face training, allowing learning in a more participatory and safe way. This work presents the implementation of this virtual environment, carried out in the February-June 2022 semester.

Keywords: Virtual reality, professional education, higher education, educational innovation

1 INTRODUCTION
The manufacture of scale models and prototypes is an essential part of the work of architecture and industrial design professionals. Due to this, training in the use of machinery for the transformation of wood, plastics, metal, and other materials is of the utmost relevance and importance.
On the other hand, the machines used to cut these materials are usually of medium and high danger, so training regarding their operation and security measures is equally important and relevant to maintain the physical integrity of students. Freshman receives training in person and with the support of an expert supervisor, who explains the security measures and the details of the operation. A problem is that students have little interaction with the machinery and are limited to watching and listening. This makes the training not entirely effective. The proposed innovation considers the use of virtual reality technologies to learn about the operation and safety measures of workshop machinery. VR environments are widely used for educational and training purposes [1] since they assure safe, immersive, and interactive spaces for learning [2]. When VR is used, students and trainees learn under a constructivist model, which enriches learning [3]. Thus, virtual reality is recognized as a strategic tool in education [4]. Regarding our interest, an increasing number of researchers have started to implement VR technologies for education and training in the Architecture, Engineering and Construction (AEC) industry [5], especially for construction safety education [6] and assembly machines training [7].

2 METHODOLOGIES

2.1 Description of the innovation

The innovation proposal consists of the design and implementation of an interactive and multimodal virtual reality environment, which is an effective complement to the traditional face-to-face training. This VR platform provides knowledge of the safety and operation measures of five medium- and high-risk machines for cutting metal and wood materials. The platform has two operation modes: tutorial and evaluation mode, and a recording system that keeps track of the activity and progress of each student. Upon entering the platform, each student must register and freely select the machine with which he or she wishes to start with. The student can, as well, review the status of her training evaluation. The detail of each of the modes of this environment can be consulted in a previous paper [8]. This virtual learning platform is installed in the VR Zone at Tecnologico de Monterrey, Campus Queretaro. It is important to mention that this platform is not exclusive to architects and designers, it can be used by any student on campus.

2.2 VR platform design and implementation process

The virtual platform development process lasted just over two years, largely due to the COVID-19 pandemic. Figure 1 shows an infographic that summarizes the entire development process of the virtual environment and the visualization of use of the metal cutter in the virtual environment.

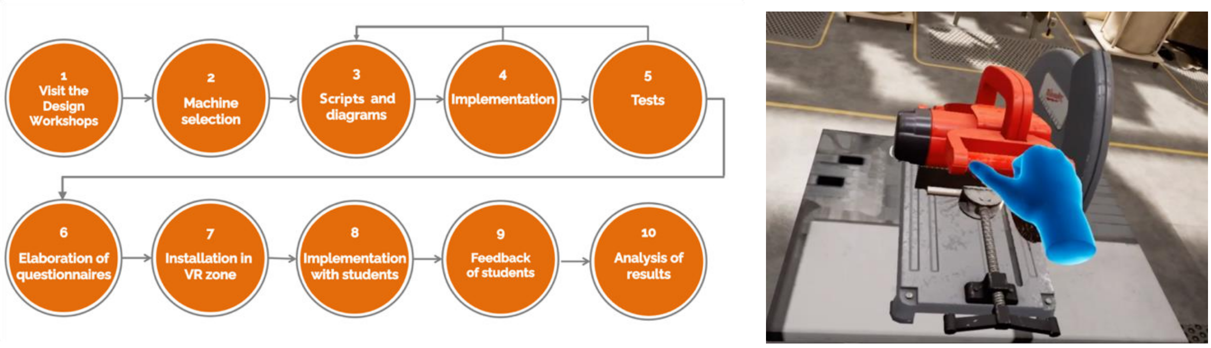

Figure 1. VR platform design process and the use of the metal cutter

All the details of the design and development process of the VR platform, as well as the adjustments made after the first implementation tests, can be consulted in a previous paper [8].

3 IMPLEMENTATION AND INITIAL RESULTS

3.1 Implementation

This innovation was implemented at Tecnologico de Monterrey, Campus Queretaro during the February-June 2022 semester in three Tec21 blocks [9]:

1. Formal representational space (Groups 101, 201 and 202)
2. Introduction to 3D (Groups 501 and 502)
3. Thought and creative process (Groups 101 and 102)

In Formal representation of space block, second semester students of the Creative Studies entrance are enrolled, while Introduction to 3D is taken only by fourth semester Digital Art students. In both cases, the students had never used the machines in the Design Workshop, nor had they received training. In the Thought and creative process block sixth semester Industrial Design students are enrolled. This last group had already taken face-to-face training in a previous semester (before the pandemic) and had some experience with machinery.

All the students, at the beginning of the corresponding block, were given general information about the project, they were explained what the experiment would consist of, and they were invited to participate. Those who accepted the invitation signed an informed consent letter. Once informed, the students participated in the experiment freely. Table 1 shows the number of students who received training without having previous experience in the use of the machines. In total, 12 students were trained in person and 25 using the virtual environment.

Table 1. Face-to-face training and in the VR environment for groups without previous experience in the machines

Block	Group	Number of students trained on the VR platform	Number of students who received face-to-face training
Formal representational space	101	5	12
	201	11	0
	202	1	0
Introduction to 3D	501	5	0
	502	3	0

Table 2 shows the number of students who tested the platform with previous experience using some of the machines. In total there were 28.

Table 2. Face-to-face training and in the VR environment for groups with previous experience in the machines

Block	Group	Number of students trained on the VR platform	Number of students who received face-to-face training
Thought and Creative Process	101	13	All in previous semesters
	102	15	All in previous semesters

Since participation was not mandatory, nor did it have a weight in their final grade, it was difficult to get students to participate consistently throughout the experiment. Not all completed the pre- and post-training questionnaires. As shown in Tables 3 and 4, the number of students who answered the post-training questionnaire is significantly lower than the number of students who started the experiment and who participated in some type of training.

Table 3. Participation in questionnaire before and after face-to-face training

Block	Group	Number of students who answered the previous questionnaire	Number of students who received face-to-face training	Number of students who answered the post-questionnaire
Formal representation of space	101	13	12	4

Table 4. Participation in the pre- and post-training questionnaire on the virtual platform

Block	Group	Number of students who answered the previous questionnaire	Number of students who were trained on the VR platform	Number of students who answered the post-questionnaire
Formal representation of space	101	9	5	4
	201	16	11	3
	202	3	1	0
Introduction to 3D	501	5	5	2
	502	3	3	3
Thought and Creative Process	101	14	13	8
	102	17	15	9

3.2 Results

To arrive at the following results, the students were divided into 2 categories: a) those who had not received training before and had no experience in handling the machines in the Design Workshop and b) those who had already received training in a previous semester. and they had some experience in using the machines.

Both categories of trainees answered a pre-training and a post-training questionnaire that included general questions about their experience with the cutting machines and specific knowledge of the machines.

3.2.1 Students without previous training or experience in the operation of machines

In this category, 4 students with face-to-face training and 12 students with training in the virtual environment completed the entire process, that is, the pre-questionnaire, training, and post-test.

In the questionnaire on specific knowledge of safety measures and cutting machines, the students with face-to-face training had an average of 5.75 correct questions out of 22 in the previous questionnaire and 7.25 correct questions in the subsequent questionnaire. There is an increase of 6.8% in questions answered correctly after face-to-face training, however the results in both cases are low.

In the same questionnaires, students trained in the virtual environment had an average of 6 correct questions out of 22 in the pre-questionnaire and 7.08 correct questions in the post-questionnaire. There is a 4.9% increase in questions answered correctly after training in the virtual environment, but, again, the results are low and similar. There is no significant difference between the two types of training. The increase in correct answers is because the answers to the questions that have to do with security measures improved, but not specific knowledge of the machines was gained.

The students who took face-to-face training pointed out as advantages 1) the possibility of asking questions and solving doubts, 2) becoming familiar with the space and seeing up close how the real machines work. The students who were trained with the VR platform said that the main advantage is 1) the possibility of making mistakes without fear, 2) the exercises can be repeated as many times as necessary without wasting material and without risk, 3) interacting with the machines to understand how they work and what are they for.

In terms of disadvantages, the students of the face-to-face training indicated that they could not use the machines themselves and that it is a long and overwhelming session, while the students of the VR platform training pointed out that there are limitations of movement in space and that the interaction with the VR controls is not always the same as it would be with the real machine.

The main change that the students suggested for the face-to-face training was to let students test the machines under the supervision of the workshop personnel. The students who used the VR environment suggested to 1) add a pause button so that the execution of the tutorial and evaluation could be paused at any time, 2) add audio instructions and not only written instructions in the evaluation mode, and 3) add a skip button so that the security module could be skipped after it was seen one time. They also suggested that, in the evaluation mode, only the fragment of the exercise that was not performed correctly could be repeated, not the whole exercise.

3.2.2 Students with previous training and some experience in the operation of machines

In this category, 17 students completed the entire process, that is, pre-questionnaire, training, and post-questionnaire. In the questionnaire on specific knowledge of safety measures and cutting machines, the students had an average of 6.41 correct questions out of 22 in the pre-questionnaire and 7.24 correct questions in the post-questionnaire. There is an increase of 3.77% in questions answered correctly after training in the virtual environment, however, the results are low. There is no significant difference between the results obtained by students with and without experience in machinery.

The advantages that the students pointed out have to do with 1) the possibility of practicing and making mistakes without risk, 2) learning on their own in their free time, 3) interacting with the machines and 4) the tutorial mode.

Regarding disadvantages, the students included 1) the discomfort and fatigue of using the VR glasses, and 2) not being able to feel what you are touching. The improvements they suggested include 1) not repeating the security module instructions more than once, 2) making the instructions clearer in evaluation mode, 3) adding more machines, not just cutting machines, and 4) checking that all user movements are detected correctly.

3.2.3 Focus groups

At the end of each block, focus groups were held to receive feedback from the students. In total there were 3 focus groups. In the first one, corresponding to the block of Formal Representation of the space, 2 students participated, one who received face-to-face training and the other in the virtual environment. In the second, the two complete groups of Thinking and Creative Process were present (even students

who did not test the platform). In the third session of focus group, in Introduction to 3D, most of the students who tested the virtual platform were present.
In these focus groups the attitude towards the VR platform was very positive. Everyone saw a value and usefulness in this educational innovation; however, they did not consider that this could replace face-to-face training, but rather complement it. They did not agree on the order in which the training sessions should be taken, but they all agreed that the ideal would be to get to know the machines live, even if only in a general and passive way, and learn to operate them on the VR platform.
Among other comments, the trainees stated that their results were not significantly better on the post-training quiz partly because they did not identify the machines by name. They suggested including photos of the machines to distinguish them more clearly.
Finally, in all the focus groups, a specific machine was pointed out, the band saw, which was the most complex to implement. It seems that with certain movements it gets stuck or does not give the expected result.

3.2.4 VR platform database

In addition to the results from the questionnaires and focus groups, we have information provided directly by the VR platform (Figure 2). The VR platform database stores the student ID, academic programme, and the last time they entered the VR environment.


Entorno virtual de aprendizaje para la enseñanza inmersiva de la operación de equipo de alto riesgo

Usuarios Resultados Evaluaciones Resultados Tutoriales

Usuarios

Buscar matricula

USUARIO	CARRERA	SESION
A01173968	LAD	2022-05-19 16:00:22.000000
A01205720	LAD	2022-02-04 12:07:26.000000
A01208968	LDI	2022-03-30 13:11:38.000000
A01274744	Otra	2022-04-20 12:46:52.000000
A01275356	LDI	2022-03-14 10:02:17.000000
A01275423	LDI	2022-02-17 12:33:26.000000
A01275850	LDI	2022-04-22 12:47:52.000000
A01351562	IC	2022-03-08 09:41:11.000000

Figure 2. Student ID, academic programme and last session in the VR environment

It also stores the number of times they have followed the tutorial of each machine and the number of times they have completed the evaluation exercises, as well as whether they have passed each one of them.
The information generated from the platform was emptied into Excel sheets with the intention of having a clearer visualization regarding the machines that were more difficult for students. The failed exercises were marked in red, those that were approved in green, and those that were not performed in white. Figure 3 shows results from students with no previous experience. A clear pattern is observed, three exercises were failed by almost half of the students. These three sections of the VR environment must be examined to assure instructions are clear enough and the programme is running without errors.

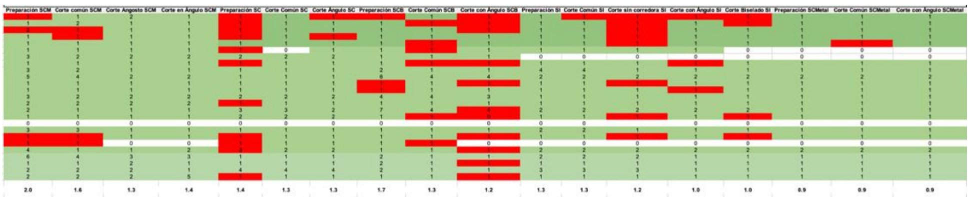
Figure 3. Excel table with the repetitions of each of the exercises for the 5 machines

4 DISCUSSIONS

The general attitude towards the virtual platform is positive. Most of students confirm that the tool helps to learn the security measures of the workshop, reduces the fear of using the machines and contributes to learning the steps to operate the different cutting machines.
All students, with or without experience using the cutting machines, agree that the main advantages of using a virtual environment for training is the possibility of making mistakes without fear or danger, repeating the tutorials and/or evaluations as many times as they need them and have free time.

There were almost no remarks about the tutorial mode. The only thing that they pointed out on several occasions is that they would like the security module not to be repeated every time the training starts on a machine. In focus groups they said that the audio instructions were precise and clear.
The evaluation module does require some changes:
a) Add, in addition to the written instructions, an audio that makes it very clear what must be done.
b) When failing, make it clearer which step was carried out wrong and make the students repeat only the wrong section.
On the other hand, one of the machines, the band saw, which was the most complex to implement, has programming errors. It seems that with certain movements it gets stuck or does not give the expected result.
Regarding the acquisition of specific knowledge about the machines, good results are not being obtained with any type of training, with or without previous experience, which indicates that perhaps there are other factors that are influencing the questionnaires, such as not recognizing or remember the machines by name or the number of days that have passed between training and answering the questionnaires.
Finally, almost all students stated that training in the VR environment should complement face-to-face training and not replace it. In the future, the intention is that 100% of the users of the Design and Architecture workshops pass the evaluation of each machine within the virtual platform to have the right to use the real machines. Consequently, it is expected to reduce accidents in the use of cutting machines and the demand for help from workshop supervisors.

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DESIGN INTO EXTREMES: EXTENDED LEARNING

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ABSTRACT
Unprecedented climate emergencies are part of everyday conversations and experiences. As students seek how to design for these challenges, some design educators are providing learning grounded in what it means to live in extreme environments. As Space Architects, the authors design suitable living conditions and life support systems for unfamiliar, remote settings. The challenge is inaccessibility to end users, their latent needs, and real-time conditions. This case study describes a student team project to design/build a habitat (Canada) for a client (Europe) and a crew of analogue astronauts who would deploy and use the habitat during an *analogue mission in a lava tube (Iceland) (*situation created/selected for its similarities to space). Design studios support students to work through a process to meet the learning objectives. Project outcomes for the curriculum presented, are functioning full-scale prototypes. However, for this case study, the process was robust but not fully functional. Extreme contexts often lead to spectacular concepts, presented as 3D-modeled concepts that never reach a built state let alone usability testing and deployment in an extreme setting. The student team's technical concepts informed a final full-scale prototype that was deployed in a lava tube and inhabited by two crews of analogue astronauts. Post-mission reports conflicted on the habitability of the concept prototype. The co-author team of analogue astronaut, student/project lead, and design educator apply an Experience-Reflection-Action model to inform extended learning through end-user engagement, contextualized methods, and survivability versus habitability.

Keywords: Habitability, analogues, prototyping, extreme environments, user-centred, life support systems

1 INTRODUCTION
The term 'extreme' is becoming part of everyday conversations and experiences and design educators are increasingly integrating extreme contexts into studio projects to introduce students to methodologies and skills for critical survival responses to unprecedented weather events. To learn how to design practical solutions for locations affected by climate change is to provide support for communities and empower design students with agency for coping with climate change and the associated anxiety of uncertainty. Hickman and colleagues documented the global prevalence of climate anxiety in young adults and its impact on their daily function [1]. They identified 'constructive or practical' anxiety as an important rational form of anxiety and response to danger that can lead us to seek more information and work toward solutions and concluded that the practice of 'solutions' is a strategy to manage anxiety arising from uncertain situations. [ibid]

Author Rebecca Solnit defines an emergency as "*a separation from the familiar, a sudden emergence into a new atmosphere*" when she writes of disasters, survival, and hope [2]. How should we design for a 'sudden emergence' into *unfamiliar* environments and what skills and competencies are needed to design and build contextually appropriate solutions. Extreme weather events bring about harsh conditions, and the most challenging factor is their unpredictability and our unpreparedness to manage the situation. Here, analogous situations are offered as a way to prepare. Learning from experiences arising from exposures to similar conditions can enhance our understanding of and resilience to terrestrial extremes and help us generate solutions for climate adaptation [3].

Extreme environments are characterized by harsh environmental conditions, beyond the optimal range for human liveability, for example, pH 2 or 11, −50°C or 113°C, saturating salt concentrations, high radiation, 200 bars of pressure, among others. These are conditions inhospitable for life. Space is one of the most extreme environments. Space architects design for inaccessible contexts and work with *Analogue astronauts* who experience life-in-space by participating in missions set in remote environments (e.g., deserts, underwater, or the arctic), living as a crew in habitats, and wearing spacesuits when performing mission-relevant roles. Learning to live off-planet requires an understanding of how to prepare for environmental hazards through analogue missions and simulators. For example, the Self-deployable Habitat for Extreme Environments (SHEE) provides a platform to conduct research into human-space activities that are distinct from living on-planet [4], including psychosocial aspects of isolation and confinement, as well as the distinctly human aspects of surviving, operating and cohabiting in a high-risk environment with a diverse set of crewmates [5]. This approach is relevant on Earth for its focus on design for remote and extreme locales, thus the authors propose design education that prepares students for unprecedented environmental events with contextualised methods, and an understanding of end-user needs and habitability design criteria.

2 HABITAT DESIGN EDUCATION FOR EXTREMES

Learning about unfamiliar settings and unpredictable situations can expand our thinking and yield innovative results [6]. A prior paper shared a 5-year evaluation of a hybrid product design education model where students design for human activity in high-risk environments [7]. The program is collaborative, explorative, and technically demanding. The students are part of a third-year studio course in designing for unpredictable and dangerous contexts. They learn from experts who mitigate risks with specialty knowledgebases and technical skills. Working in teams, they self-project-manage their way to full scale, functional prototypes that are evaluated through design scenarios, expert feedback, and site-based test protocols, to meet the following course learning outcomes:

- *Confer with user groups and manufacturers in the development of design solutions*
- *Assess the essential user criteria through observations, meetings, role-playing, ethnographic studies*
- *Formulate design criteria necessary to generate and test concepts and prototypes*

In extreme environments, humans require technical products and personal protective equipment (PPE) to survive. This curriculum focuses on both short and long emergencies for user's needs. 'Short emergency' is aligned with survivability while 'long emergency' is aligned to the liveability of conditions. While Kunstler uses the latter term to describe the catastrophic impacts of the techno-industrial phase [8], the authors apply it to design adaptations for habitability. Within this curriculum, design development requires applying user-based research insights, user criteria, and user testing to achieve a concept that is feasible, buildable, and testable. This paper shares a case study emerging from the same curriculum, but with challenges of scale and inaccessibility of the locale and the latent end-users (analogue astronauts). The case study method was chosen to capture and share the distinct elements of this project and the co-authors, including their reflections, as guided by the Experience-Reflection-Action (ERA) cycle [9]. The project was grounded in project based learning and Problem-Based Learning (PBL); both are active methods aligning to the pedagogical concepts of learning-by-doing / learning-by-discovery [10].

3 CASE STUDY: ANALOGUE MISSION IN ICELAND 2021: EXPERIENCE

A client-generated brief was provided. Figure 1 shows the setting and specific access details for a habitat to be designed and prototyped as a concept for an analogue mission set in an Icelandic lava tube (Stefanshellir, August 2021). The client brief specified that: "*the habitat needs to provide shelter for three analog astronauts for the duration of the analog mission: this involved two nights inside the habitat. As we are targeting multiple back-to-back missions, the habitat should be robust enough to be used in at least two missions. Preferably, the structure can be re-deployed for future missions.*"

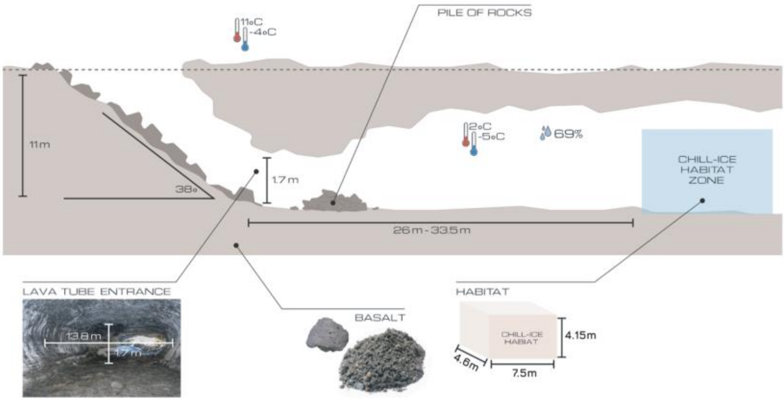

Figure 1. Stefanshellir lava tube access, geology and environment (Image Credit: B.van Rikxoort)

3.1 Design Requirements - Survivability versus Habitability

Design Educator's Experience: The "mission critical" requirement was for habitat set-up to require less than 8 hours, as that is the limit of the astronaut's portable oxygen supply. Other requirements to address include portability (load dimensions and weight) given the steepness of the terrain (Figure 1) and the need for the habitat to be freestanding within the basalt lava tube. Remaining criteria to address were the crew's use of the volume including: "*minimal living and working space for the crew of three, for which multiplexing of areas will be vital! The space will need to provide: a hygiene area: somewhat shielded from the rest of the interior, minimal work and communications area, sleeping area, EVA suit donning, and storage (EVA suits, instruments, utilities)*." The team-developed design hierarchy had eight criteria (Figure 2a);01-04 address survivability and 05-08 extended to habitability.

Figure 2. a) *Design Criteria Hierarchy and b) Design Validation process (Image Credit: B.van Rikxoort)*

Student/Project lead's Experience: With certainty for use at the core of this project combined with the fast-approaching deadline, our team was urged to deliberate what it means to design for survivability versus habitability. While additional design considerations were proposed - 'performance vs testing methods', 'availability vs cost', and 'leave no trace' ultimately, the client's specifications guided our design decisions when working through the design validation process (Figure 2b).

3.2 User testing:

In analogue missions, the function and safety of design solutions are evaluated and optimized by focusing on user-experience. The team focused on human factors (Figure 3) to support concept evaluation and development. Habitability design applies human-centred design principles at each step of the process. NASA's Habitability Design Centre stresses the importance of early prototyping and testing to save cost and to improve crew experience via 3D-modeling/prototyping mock-ups for hands-on evaluation by both their habitability design and their human factors teams [11].

HUMAN FACTORS	FREQUENCY	IMPORTANCE SAFETY, HEALTH, WELL-BEING	HIERARCHY SCORE (importance X frequency)	ESSENTIAL FOR MISSION SUCCESS	POTENTIAL FOR MITIGATION
HUMAN INTERACTIONS					
Isolation from the world	5	5	25	N	N
Time alone (being by yourself)	2	4	8	N	Y
Time with others	5	3	15	Y	Y
PRIVACY					
Changing/hygiene privacy	5	5	25	N	Y
Lack of privacy	5	3	15	N	Y
Bathroom privacy	5	5	25	N	Y
Sleeping privacy	3	2	6	N	Y
ENVIRONMENTAL INTERACTIONS					
Moving/walking space	4	4	16	N	Y
Access to natural light	2	2	4	N	Y
Breathing fresh air	1	5	5	N	N
Greenery	1	3	3	N	N
Airlock space for 2 people	5	5	25	Y	Y
Working/communal environment	4	3	12	N	Y
Temperature	4	5	20	N	Y

Figure 3. Human Factors criteria (Image Credit: B.van Rikxoort)

Student/Project lead's Experience: Using test protocols our simulations yielded insights for unpacking/packing the habitat from the transport bag, such as: ...difficult to grip with gloves, difficult to breathe (with mask on), heavy for user…putting the shell and floor into the bag was a struggle…5 min 10 seconds time to pack up (Criteria 01,02 and 06). In our final report, we stated that "User testing is focused on the users and how they understand and interact with the habitat. Looking at the human factors, we needed to determine; how all of the design considerations will be filtered for the end results, how the users will comprehend how the habitat will be put together, and how they will interact within it." [12] **Design Educator's Experience:** Design validation involved user testing, feedback and review of the design criteria against test results (Figure 2). This led to the teams' concept prototypes (Figure 4).

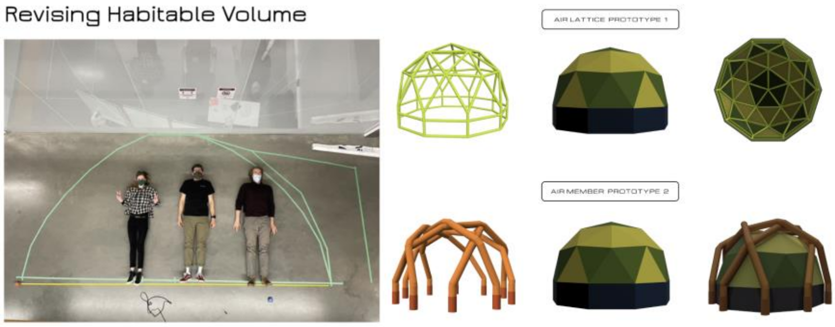

Figure 4. "FullAir' Habitat" concept development (volume, structural testing) (Image Credit: M.P. Alary)

The concepts referenced Buckminster Fuller's geodesic dome; a structural design proven to be suitable for habitability in extreme environments [13]. By week seven the team had built many sample constructions and two full-scale concept prototypes using innovative structural inflation strategies. Despite extensive prototyping, testing and revisions, neither concept was structurally testable as a habitat for the upcoming analog mission. The next section offers the co-authors (three-way) insights.

4 INSIGHTS: USER TESTING HABITATS IN EXTREMES: REFLECTIONS

The student's rigorous research and concepts informed the final construction of the full-scale concept prototype and supported documentation for the analogue crews on deployment/redeployment, care and maintenance of the habitat. The client independently documented the habitat project's contribution to research on analogues [14]. This paper sought the perspective of an Analogue astronaut:

*Table 1: **Analogue Astronaut's Experience/Reflection:** Daily Log Extracts, S.C. Crew Engineer*

01 / 06	DEPLOYMENT / REDEPLOYABLE
	"we had it up quite quick [within 4 hours] but once it was up we noticed a leak so this is something we need to monitor and repair. This is unexpected and will add to our tasks and workload.."
02 / 03	PORTABILITY / PACKABILITY
	"Walking up/down from the cave entrance was dangerous. I couldn't see the obstacles due to my helmet visor (limited visibility) and fog. We could only go one person at a time, and carrying heavy loads made it even more dangerous without the right safety measures."
04	FREESTANDING STRUCTURE
	"The structure was leaking on the first day (two tubes leaking) and we had shifts to keep it up. The poles help but aren't keeping the structure up. Night two: the structure collapsed at the airlock end and this meant more water entered the habitat and it affected the air flow inside"
05 / 07	HABITABLE SPACE / AIRLOCK
	"…the volume feels fine for the three of us, but more interior organization would be great. I kept my laptop dry and other items using drybags, but not everyone has these. With so much dampness (humidity and water on the floor) it's difficult to stay warm unless we're in our sleeping bags. My crewmembers are cold as their bags are not rated up to -10° C (the temperature at night was around 0 C). My sleeping bag was damaged in transport by the sharpness of the rocks... hygiene station/airlock has a bad odor - it's throughout the whole habitat because of the lack of airflow… there is no privacy and it would be good to have sound insulation too. We're a mixed gender team so the option of more privacy while getting in and out of our suits and for getting ready for sleep was lacking… we can't heat water because our electronics stopped working… repairing the leaks has affected our schedule and everyone is exhausted... two air structures failed so the habitat partially collapsed at the airlock end, which affected hygiene (that was a big problem)."
08	MATERIALS
	"...I can feel that the floor has layers but it still feels cold. It's so humid inside the habitat. I'm questioning the suitability of inflatables for a lava tube environment…the surrounding surfaces (mostly basalt) are extremely sharp."

Student/Project lead's Reflection: Reviewing the Analogue Astronaut's feedback (Table 1) led to many reflections, including these: *we overlooked the need for testing the habitat in a diverse range of temperatures, and underestimated how this can impact the success of each factor we designed; situating Team discussions in environments where comfort is reduced, (e.g. a confined space) may have helped to provide empathy into psychosocial challenges, and understanding where redundancy should be incorporated may have also been revealed to us in this setting.*

Design Educator's Reflection: This project yielded insights in user testing and test protocols for extreme, unfamiliar and remote contexts. When mapped onto the Team's Design Criteria (Figure 2) these insights include: repairability and replaceability are complex in extreme environments (01/06: Deployment/Redeployment); cultural beliefs impact habitability so there was a need to prioritize forms of privacy (05: Schedule of Use); and extending test scenarios didn't involve design for worst case scenarios and possibilities beyond the obvious. (05/07 Scenarios of Use)

Triangulated Reflections: Habitability design is a complex learning challenge. Collectively, the co-author team's insights focused on empathy, end-user criteria and scenario-based testing. Post-project, the faculty team also engaged in discussion and debate on how to [ethically] facilitate and integrate end-user testing for remote, unfamiliar and extreme contexts, and how to extend these insights into new learning approaches that can be evaluated in future project iterations?

5 DESIGNING EXTENDED EDUCATION THROUGH EXTREMES – ACTIONS

Time and experience have shown that revolutionary ideas come from extremes; extraordinary circumstances that will require design programs to expand how user testing is integrated into processes and projects. discussing the insights yielded the following three high level themes and suggested actions to extend design learning opportunities for unpredictable and dangerous contexts.

1. Technology for understanding context and end-user testing; the ethics and logistics of accessing extreme contexts preclude site visits but Virtual Reality (VR) can offer the experience of unfamiliar, dangerous contexts within ethical boundaries and is an emergent area of practice. [15] VR also allows for rapid and scalable 3D-modeling of true-to-size structures and immersion in the space, which can help in contextualizing design requirements prior to building.
2. Empathy and humanity are challenging mindsets to teach alongside technical content. Conversations are important to link studio project experiences to climate change thus having discussions of lived experiences is recommended over 'information dumps'. Environmental educators like Campbell advocate for a 'contemplative, existential perspective' to process anthropocentric emotions [16] which is relevant to designing for the 'long emergency'.
3. Analogues, end-user needs and habitability; Situational preparedness should prioritise exploration and prototyping prior to a climate emergency, since a 'sudden emergence' involves trying to adapt and design simultaneously. When designing analogues, students are trying to understand end-user needs without experiencing them directly, but seeking latent end-user needs, needs that are important yet not obvious or outwardly spoken by the average user, can address this gap [17].

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EVALUATION CRITERIA FOR NEEDS STATEMENTS IN DESIGN EDUCATION

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ABSTRACT
Problem definition is essential to develop innovative products. The needs statement is a framework expressing design problems or user needs in a single sentence. In design education, needs statements are sometimes used to teach problem definition. Many novice students who do not major in design struggle to generate the needs statements and to understand key criteria. On the other hand, educators seem to have standard evaluation criteria. As a first step to effectively supporting design learners in writing needs statements, this study aims to identify design educators' evaluation perspectives for needs statements. Semi-structured interviews with nine educators and qualitative content analysis were conducted. The results revealed an evaluation perspective on the function and quality of the statement. The five perspectives for evaluating the function of the statements are **Adequacy of expression**, **Consistency with the theme**, **Whether it is based on research**, **Feasibility of idea generation,** and **Consistency with the solution**. The three perspectives for evaluating its quality are **Newness**, **Clarity,** and **Efficacy**. The results corresponded to the criteria of idea creativity evaluation. Although these results were obtained in a limited context, it is expected to be the basis for supporting students' activities on framing, problem definition, and user understanding in design projects.

Keywords: Problem definition, needs statement, user understanding, user research, empathy

1 INTRODUCTION
Designing is an iterative process of divergence and convergence, moving back and forth between problems and solutions. The Double Diamond Model (Design Council, 2019) describes the process in four stages: *Discover*, *Define*, *Develop,* and *Deliver*. The model described the process as a series of steps with no clear distinction between each step. Designers have taken a variety of strategies and approaches to generate solutions to unstructured and open-ended problems, and several kinds of literature have studied the process of individual activity in design (Abidin et al., 2008; Ito et al., 2022; Murray et al., 2019). Based on the literature, essential factors in generating innovative ideas are recognising, framing and defining user needs.
Much research has been conducted on problem definition and framing. Abduction, known as one of reasoning, is essential for generating creative solutions (Kolko, 2010). Dorst (2011) states that framing is a core practice among abductive reasoning methods and that research should be conducted to understand it in more detail. Several studies have been conducted to understand the activities of individuals in problem definition. For example, experts have comprehensive mental representations based on broad relevancy perception (Björklund, 2013). Another research found that problem framing has influenced idea generation (Wright et al., 2015).
Design education for non-designers aims to teach the designers' approach and mindset. Since there are many obstacles in defining design problems, a framework called the "needs statement" is used (Lewrick et al., 2018; Stickdorn et al., 2018). Needs statements are expressed, for example, in a format of "{who} needs {what} because {why}." This statement expresses in one sentence which users are targeted, what kind of needs users have, and why users need solutions to let users achieve their needs. This statement includes "insight" gained through user understanding. The statement also indicates the results that need to be achieved by the solution and the requirements met by the solution, which serves as a starting point for idea generation. Despite this critical role in the process, it has been found that students experience many difficulties writing needs statements (Loweth et al., 2020).

While several studies of the problem definition exist, there is a lack of clear guidelines in design education for needs definition. There is a need to identify guidelines in educational settings to develop effective strategies and approaches for learners. In particular, there needs to be more research on needs statements, although they are used in many educational fields. Educators have shared clear evaluation metrics for needs statements based on good/bad cases from experiences. Clarification of these guidelines could lead to improvements in design education.

This research is the first step to effectively supporting design learners in design education. This study aims to investigate the perceptions of educators involved in design education regarding problem definitions. The research question of this paper is “What are the evaluation perspectives of the needs statements of educators involved in design education?” and “What kind of content do educators evaluate and how?” Semi-structured interviews were conducted with nine interviewees involved in design education, and the interviews’ content was analysed qualitatively.

2 METHOD

This study conducted interviews and analyses to determine the perceptions of educators involved in design education regarding problem definition.

2.1 Backgrounds of Interviewees

Figure 1 shows the backgrounds of the interviewees. The interviewees of this study were educators involved in design projects and project-based courses for innovation creation offered at Japanese universities. Projects they are involved in are also for university students who do not major in design to learn about design approaches and mindsets to create. Since there are differences in framing approaches between different cultures in different countries (Lotz et al., 2014), interviewees were selected in a limited context. Seven of the nine had been involved in a project-based learning course at the authors’ university for two to seven years as educators, one had an arts background, and the rest had engineering backgrounds. In the course, teams of engineering graduate students and third-year undergraduate art students work together using a user-centred design approach. In the project, a partner company gives a theme, and teams aim to develop a product on the theme in five months, as done in the ME310 at Stanford University (Carleton & Leifer, 2009). Two of the nine interviewees not involved in this project were also involved in similar innovation projects as educators. The two interviewees were included to generalise the results to design education for engineering students in Japan.

2.2 Semi-structured Interview

Interviews were to investigate the perception of educators on problem definition or evaluation perspectives of educators on needs statements. The interviews were exploratory, focusing on characteristics of good and bad examples of problem definition from past projects, the role of problem definition in design processes, and common mistakes made by students (Figure 1). Each interview lasted thirty minutes to an hour, and all dialogues were recorded. The first author conducted all interviews. Because it was a semi-structured interview, interesting responses were explored in depth.

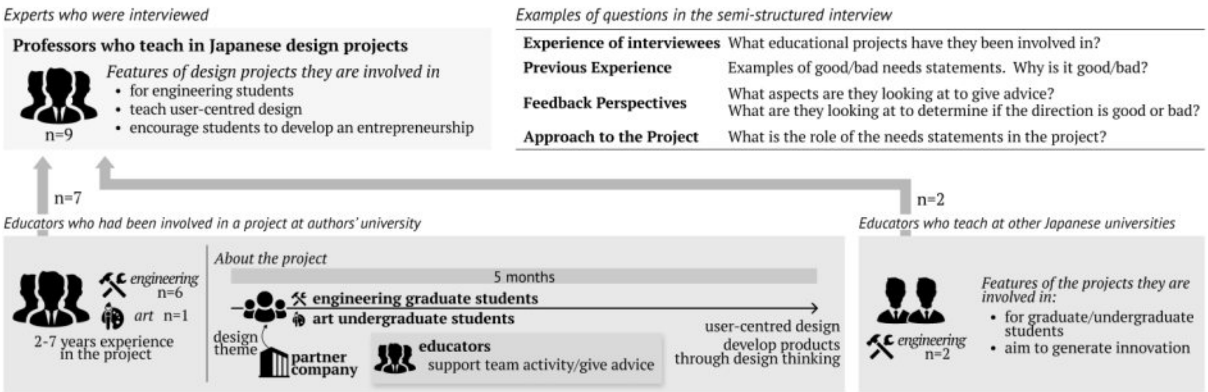

Figure 1. Backgrounds of interviewees and examples of questions in the interview

2.3 Qualitative Content Analysis

All recorded interview dialogues were transcribed, and the content analysis was conducted following Mayring (2021), as shown in Figure 2. First, the first author read the transcribed content several times to become familiar with the data. Next, statements relevant to the problem definition were identified and extracted. Then an inductive coding approach was used to interpret and conceptualise the transcriptions. This process was repeated, adjusting the meaning of concepts and the level of abstraction. Those concepts were merged when concepts overlapped, and when new structures were found, concepts were subdivided. Integration and subdivision were continued until saturation was reached, and finally, the results of the interviews were structured. After structuring, the two authors discussed and confirmed the definitions, agreed on all definitions and concepts, and completed the content analysis with a final confirmation.

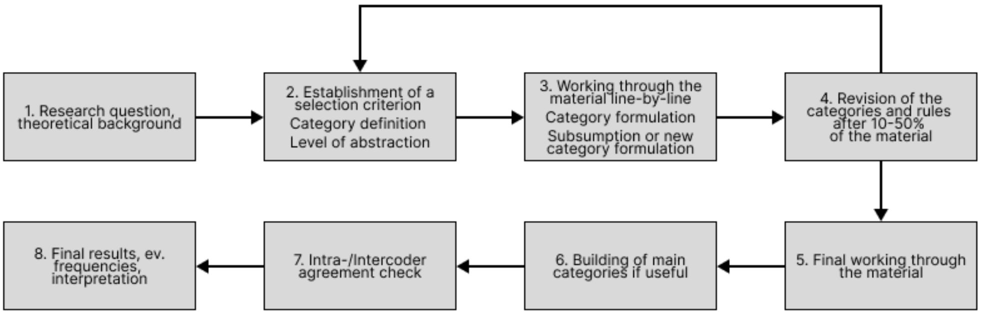

Figure 2. The procedure of content analysis (Mayring, 2020)

3 RESULTS

The content analysis generated concepts about the evaluation perspective on needs statements. The interviews contained much of the same content regardless of the project in which the educator was involved. Therefore, it was possible to exclude project-dependent stories from the analysis and only include general content. This section describes the fact revealed from interviews and the concepts generated from the analysis.

It was revealed that educators instructed the students to prioritise the development of a solution rather than expressing the needs statements. Interviewees all mentioned that it was impossible to determine whether the process would be successful based on the need's statements alone. When educators evaluate the processes students conduct, it is essential to evaluate them based on overall outcomes, not only needs statements but also the ideas presented, the proposed experience with the prototype, and the results of user tests. However, educators mentioned that the signs of typical failure may be discerned from the needs statement. There are several cases where educators can detect unsuccessful processes.

To determine whether needs statements work properly, educators have checked from two main perspectives; expression and content. **Adequacy of expression** is a perspective to check whether the problem situation and needs were extracted properly and whether functions are not included in the statements. "*The students often say that the problem is 'the user wants to do something, but in reality, he/she does nothing.' However, teachers probably think it's two sides of the same coin, so there's no difference.*" Table 1 shows the evaluation perspectives on the expression of needs statements.

Table 1. Concepts relevant to the evaluation of expression of needs statements

Category	Definition	Typical examples of failure
Adequacy of expression	Can it extract the problem situation and needs and include features?	The defined need is the flip side of the problem situation.

Table 2 shows the four perspectives for evaluation of content adequacy; **Consistency with the theme**, **Whether it is based on research**, **Feasibility of idea generation**, and **Consistency with the solution**. **Consistency with the theme** is a criterion to evaluate whether it aligns with the design theme, which indicates the issues to be addressed in the project. As one of the interviewees said, "*At the beginning of the project, I ask students, 'Is there something wrong somewhere? Is what you are aiming for correct?'*

I think that is rather important." Educators check that the perspective set by students matches the project scope.

Whether it is based on research is a perspective to evaluate whether it is based on facts obtained from surveys conducted to gather information from users and stakeholders. The evaluation was based on users' experiences described in needs statements, whether they are difficult to imagine and mixed with students' imagination and past experiences, leading to assumptions far from the facts. For instance, one explained: "*(...) when young people imagine the elderly, students' understanding of the elderly is limited, so students tend to create new stories, mixing in stories about the elderly students have seen in TV dramas or newspapers.*" In this perspective, educators check whether these kinds of biases are included.

After the problem definition, there is always the generation of ideas and the development of solutions. **Feasibility of idea generation** and **Consistency with solutions** were mentioned as perspectives to check the consistency with those ideas and solutions. **Feasibility of idea generation** was evaluated by inferring the ideas that could be generated in the problem setting and whether the statements would work appropriately as requirements. **Consistency with the solution** was the perspective of whether the problem the solution addresses is consistent with the defined problem.

Needs statements were checked to determine whether statements worked not only from the perspective of evaluating the logic as described above but also from evaluating the appropriateness of the statements.

Table 2. Concepts relevant to the evaluation of whether needs statements work properly

Concept	Definition	Typical examples of failure
Consistency with the theme	Is it consistent with the given design theme?	Out of the scope of the project
Whether it is based on research	Is it based on facts obtained from research?	Based on delusion or stereotype
Feasibility of ideation	Does it work properly as a requirement for idea generation?	Unstable as a starting point for idea generation
Consistency with the solution	Is there consistency between the problem that the solution addresses and the defined problem?	It does not indicate the problem that the solution solves

Other than confirming the above perspectives that assess if the needs statements support the design process, the educators had different views on assessing its quality. While educators stated that it is impossible to identify good cases based on the needs statement alone, educators described what perspectives have been used to identify typical failures. As a result, three perspectives existed, as shown in Table 3 below; **Newness**, **Clarity**, and **Efficacy**.

Table 3. Categories relevant to the evaluation to identify typical failures

Concept	Definition	Typical examples of failure
Newness	The problem defined is new, and there is an expression of surprise, discovery, and discomfort from the investigation. Something that is different from existing things and does not feel obvious.	What is commonly said Obvious before researching Normal/common sense / generalised
Clarity	The focus of the defined problem is narrow and concise. Not too complex or abstract.	Too much information, too abstract, too broad scope
Efficacy	The defined problem is essential to address and has several subjects. The problem is not too trivial or a particular problem with few subjects.	Too trivial, Not urgent, Not significant to tackle, Too small target

Novelty is a perspective that evaluates whether the defined problem is new and expresses surprise or discovery. Typical examples of failure were defining a problem for which there are many existing solutions or explaining a problem situation that can be understood without research. One educator said, "*I want it to express the kind of surprise that students first discovered when students interviewed.*" Another said educators would evaluate it as good if it expressed "*(...) something that has been overlooked or passed by unnoticed.*" On the other hand, many comments about needs statements were not novel, such as: "*Isn't that something you knew before interviewing?*"

Clarity is a perspective that evaluates whether the defined problem is expressed accurately and concretely. Typical examples of failure were: too much information in the text, too abstract and unfocused, and too broad a scope of the defined situation. To quote from the interviews included, "*The target user needs to be clear.*" and "*the ideal state that the user is aiming for and how it should be achieved.*"

In terms of **Efficacy**, this perspective evaluates whether the defined problem is an important one to be addressed and whether there is a specific target audience. One educator asked in a project, *"How many people would be happy with that if designers met the defined needs?"* Another stated, *"Is it valuable to bridge the gap (between the current problem situation and the defined ideal situation)?"* Typical examples of failure include defining a trivial issue or targeting only a few people.

4 DISCUSSIONS

The analysis revealed the perspectives with which educators involved in design education evaluate needs statements. There were five perspectives to assess if the needs statement worked and three attitudes to consider its quality.

Educators evaluate logic and adequacy when evaluating whether the needs statements work correctly. Through content analysis, five perspectives were identified: **Adequacy of expression**, **Consistency with the theme**, **Whether it is based on research**, **Feasibility of ideation** and **Consistency with the solution**. These perspectives may have been used because students are new to the design approach and often generate needs statements that could not work as frames. Since framing is a specific skill in design activities, students need to gain its ability through projects. Therefore, these evaluation perspectives can effectively check whether the result of the framing could work or not.

While educators mentioned that the needs statements alone could not determine whether the process is good or bad, they describe the differences between good and bad needs statements. Regarding the evaluation perspective on quality, three perspectives were identified: **Newness**, **Clarity**, and **Efficacy**. The concepts generated in this research correspond to the indicators commonly used in the creativity evaluation of ideas proposed by Dean et al. (2006). In idea assessment, the rarity of the idea and whether the idea itself is surprising (originality) are evaluated, consistent with the concept obtained in this study, **Newness**. The **Clarity** defined in this study also corresponds to idea creativity evaluation metrics, and both evaluate the degree of elaborated and precise description of actions, outcomes, and situations. While Effectiveness evaluates whether a defined problem is essential to solving or has some number of stakeholders, the same evaluation perspectives are included in idea evaluation. Problem definition is known to proceed simultaneously with solution development (Dorst & Cross, 2001). Sometimes a solution is accompanied by a more detailed description of the problem or a reframing of the problem. Conversely, an improved definition of the problem can lead to the creation of a better idea. From this point of view, it is natural that the evaluation done on the concept relates to assessing the problem definition statement.

This study also has the following limitations. First, this study considers projects that adopted a design framework in which users' needs are identified through empathic understandings of the users. Evaluation perspectives in the other types of projects are not considered, and the results from other types of projects could differ from this study. Second, as this study investigated perceptions of problem definition by teachers involved in design education, it is debatable whether these can be used as-is as evaluation criteria of the needs statement. In addition, the affiliations of the interviewees in this study make the results may depend on a specific context. We believe conducting further research with design educators from various universities is essential to generalise the findings. Third, problem definition and solution development co-evolve (Dorst & Cross, 2001). Educators also mentioned that assessing students' processes based only on needs statements is impossible, and comprehensive evaluations are needed. As the degree of elaboration of problem definition changes along the project, the evaluation perspective may change accordingly. However, the present study does not include this aspect. We believe that additional interviews should be conducted to consider the co-evolution of solutions with the project's progress.

While several studies of the problem definition exist, there is a lack of clear guidelines in design education for needs definition. Despite the above limitations, this study contributes to identifying evaluation perspectives on needs statements that had been tacit knowledge. This study could be the basis for supporting students' activities such as framing, problem definition, and user understanding.

5 CONCLUSIONS

This study investigated the educators' evaluation perspectives for needs statements generated in design projects. Semi-structured interviews were conducted with nine educators involved in design projects with college students. Content analysis was used to identify educators' evaluation perspectives. The results revealed five evaluation perspectives for checking whether a problem definition statement works properly and three perspectives for evaluating the quality of the problem definition statement. Evaluation of whether the needs statement works was based on the following five perspectives; **Adequacy of expression**, **Consistency with the theme**, **Whether it is based on research**, **Feasibility of idea generation**, and **Consistency with the solution**. Evaluation of the quality of the needs statements was based on the following three perspectives; **Newness**, **Clarity** and **Efficacy**. The outcome was a structured perception of the educators involved in the design project in problem definition. The results are expected to help create clear instructional policies in educational settings and guide and support the process involved in problem definition.

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SUSTAINABLE PRODUCT DESIGN EDUCATION THROUGH AN APPRECIATION OF THE LOW-TECH

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ABSTRACT
The paper presents a case study on the implementation of Low-Tech development model to teach sustainability in design-led programmes. The author argues that sustainability education should include not only the technical aspects of sustainability theory but also the underlying social aspects. The low-tech approach fits well in design-led modules since it encourages students to consider appropriate technological solutions for design projects while focusing on user behaviour to develop articulate solutions. The study explores the pedagogical approach of the content used to teach the design module and introduces a low-tech design workshop to aid students in implementing learning. The results of the study show that students' understanding of sustainability and low-tech design increased, and they were able to implement mechanical solutions to design problems while considering the social element of their design outputs.

Keywords: Product design, design education, sustainability, low tech, studio practice

1 INTRODUCTION
Philippe Bihoux, in his 2014 work, *L'Âge des low tech: vers une civilization techniquement soutenable* suggests that developing increasingly high-tech solutions to address the sustainability crisis is a hopeless cause [1]. Instead, an appreciation of energy sobriety and material conservation, as we move to embrace low-tech developments, would yield more impactful results.
Internationally, design courses offer a range of approaches to teaching and embedding sustainability theory amongst their student body. From focusing on behaviour change [2], and imparting knowledge on sustainable design and manufacturing approaches [3] to a focus on developing product solutions which encourage improved product lifespans [4] there are many worthwhile pedagogies which can be imparted to our students.
Low-tech approaches to sustainability require designers to question assumptions held about users' energy needs through the lens of energy sobriety. Their solutions should reduce technological intensity and complexity whilst encouraging a commons approach to the implementation of a solution.
As a method of sustainability education within design-led programmes there is little documentation of this approach being widely utilised although the theory's core ideas of behaviour change through a better understanding of user needs and requirements[5] follow the common practices of User Centred Design that many course programmes map.

2 AIMS AND APPROACHES
Many courses are moving toward an integrated model of sustainable education within their programme frameworks rather than standalone sustainability modules [6]. This allows for education systems to not only educate students on the technical aspects of sustainability theory but also the underlying social aspects. This approach allows for a deeper, less superficial understanding of sustainable development. For this reason, it was decided to implement additional sustainability themes into more modules within the programme architecture. The Low-Tech approach fits well within the case study module as students were already being asked to consider non-electrically powered solutions for design projects as well as considering user behaviour to develop articulate solutions. It was decided that module learners should:

- Have an increased understanding of sustainable development.
- Be able to implement mechanical solutions to design problems.

- Be able to consider the social element of their design outputs.

2.1 Practice-Based Learning
Practice-based learning for design education is a well-established approach and is often a primary tactic in many design education programmes [7]. It has been noted that it can also be an especially useful approach for comprehending technical systems [8]. These are major themes within the module requirements and so it is a natural pedagogical approach for this type of class. It will be important however to balance the delivery and scaffolding of the sustainability theory within the design-led paradigm that the module structure requires. At this stage in the education cycle students on the programme tend to have shorter time limits for design projects to allow for repeated practice of problem-finding, problem-framing and problem-solving and as such, outcomes are likely to achieve lower levels of resolution. However, there should be plenty of opportunities for students to explore and explain their understanding of the subject matter through their design work.

2.2 Technical Content
Students are expected to undertake a large amount of Continuous Assessment work in class and so formal teaching sessions were shorter in length than may ordinarily be expected. This deficit was augmented with additional tailored verbal instructor feedback. Students were presented with several pieces of literature to read and were instructed in the following subject matter through lectures and case studies:

- Introduction to sustainable product development
- The low-tech development model.
- Simple Mechanical Systems

Additionally, video and online resources were provided to students through the Virtual Learning Environment and links to parallel themes in concurrent modules were highlighted to allow students to understand and implement knowledge provided from taught modules in other areas of the programme syllabus.

2.3 Low-Tech Workshop
As additional educational activities, an intensive Low-Tech design workshop was developed in two parts to allow students to develop design ideas which were deeply rooted in the low-tech development framework.

The first part of this workshop involved the students undertaking several activities (cause and effect diagramming, ecosystem mapping) and then developing their design ideas using prompts from an ideation card game developed for the workshop. This card game ran for several rounds allowing students to develop responses based on the card prompts which were developed based on the Low-Tech framework.

The second session allowed students to quickly evaluate and prototype their mechanical design ideas through prototyping mechanisms with a simple kit of mechanical components. Students were able to use given components and rapidly prototype their own custom parts to understand the implications of their mechanism design.

3 RESULTS

3.1 Sustainability Learning
Anecdotally the current generation of students is said to be the most aware cohort ever regarding the climate crisis. To set a benchmark for the understanding of how sustainability considerations were understood within the student body, regarding product development, the class (ordinarily 30 students but for the initial session included some visiting students) was asked to consider the most important consideration when thinking about sustainable design. Thirty-five results were recorded, and they were analysed thematically into the following themes.

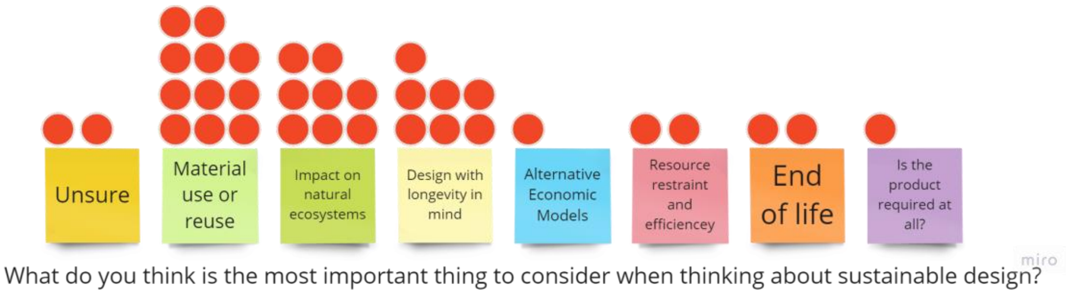

Figure 1. Thematic grouping of a poll to understand the class's view of important considerations in sustainable design

The area with by far the most responses related to material use, which is understandable as it is often a central theme in sustainability discussions. This is also related to the broader theme of resource restraint and efficiency. The next largest grouping of responses related to a product's impact on the biosphere with ideas around the life of the product as the third largest theme.

When students were asked to reflect on their understanding of the phrase *low tech design* there were similarly large groupings of responses.

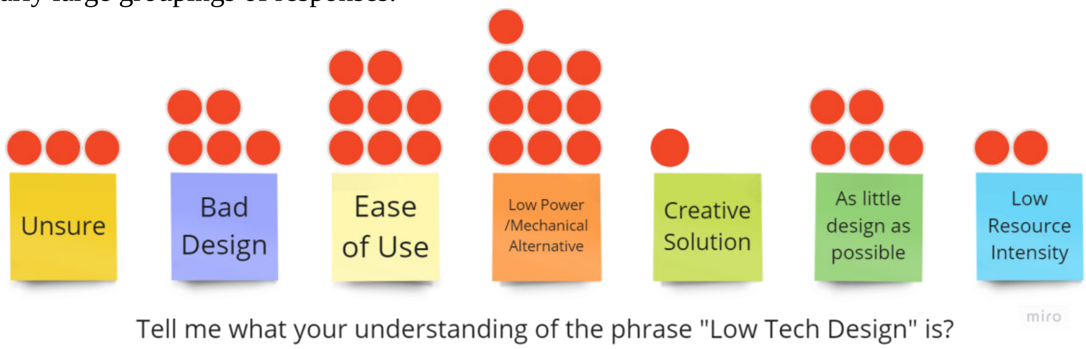

Figure 2. Thematic grouping of a poll to understand the class's understanding of the phrase low-tech design

With these groupings, many students understood the phrase to relate to finding mechanical or low-energy solutions, which may have been due to students' prior knowledge of the upcoming design brief. Students also identified the importance of ease of use and *as little design as possible* as important requirements. There was also a markedly high response of students' negative reflections on the phrase and equating it with poor design outcomes.

At the end of the programme of study, students were polled on their understanding of sustainability within a general context and within the more specific realm of product development. Students responded to several statements using a Likert scale to indicate their agreement with a statement. Seventeen students responded to this poll, around 50% of the number who took part in the poll at the beginning of the project.

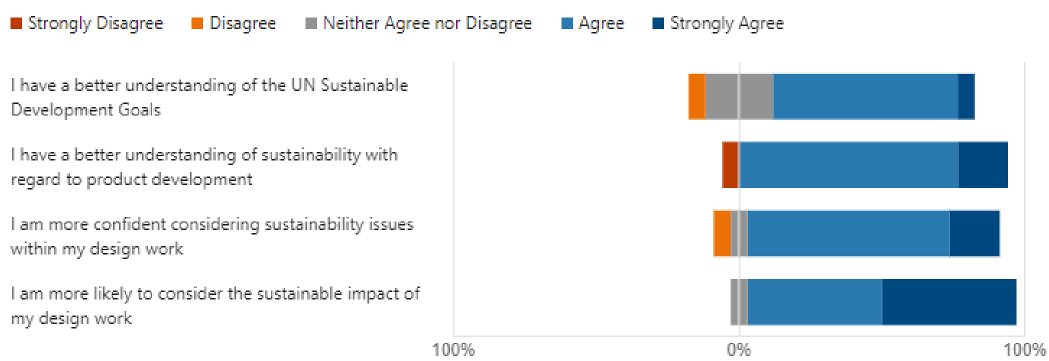

Figure 3. Results of end-of-course polling to understand student learning around sustainability

Most students found the programme of study to be positive. Nearly all respondents had a better understanding of the UN Sustainability goals and all bar one felt they had a better understanding of sustainability within the context of product development. More significantly many students were more confident considering sustainability in their ongoing design practice and nearly every student who responded was likely to consider the sustainability aspects of their design concepts moving forward.

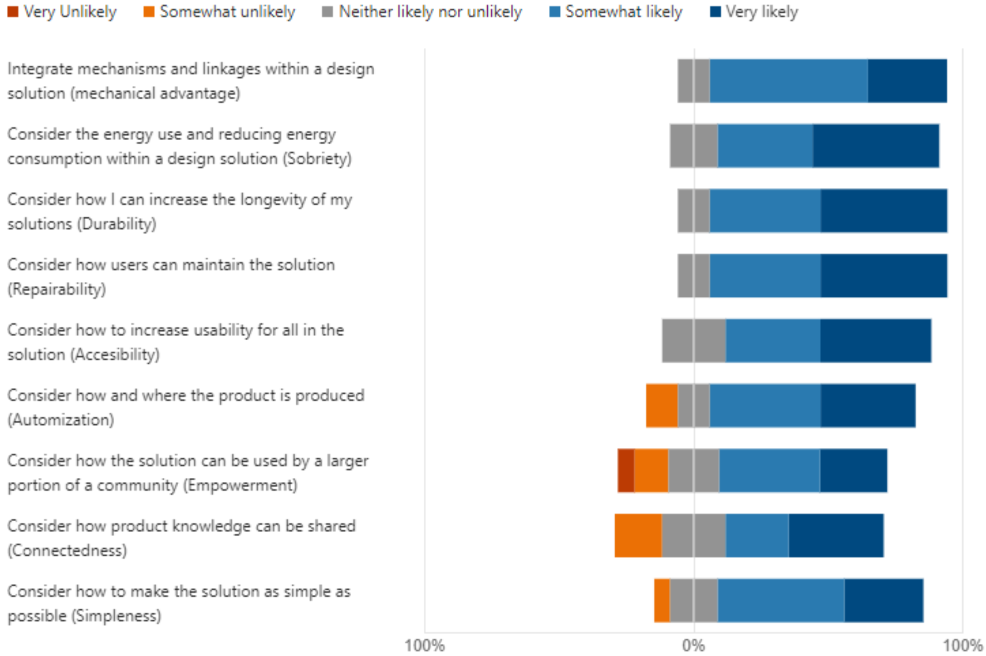

Figure 4. Likert Graph to understand the adoption of knowledge and competencies around Low - Tech Development

Overall, the programme of study allowed most respondents to have a high likelihood of implementing many of the Low-Tech method's themes into their future design work. Considerable success was had with students understanding the importance of energy sobriety, durability and repairability which are all important goals.

The themes with the lowest confidence among students were those concerning some of the social elements of the low-tech method. Students were less likely to consider user empowerment and connectedness within future design projects.

3.2 Low-Tech Ideation Game

Students spent one 4-hour class session undertaking a serious game to help them develop their design ideas within the Low-Tech framework. Each team was provided with a series of primer tasks based on understanding the product ecosystem for their design space as well as cause-and-effect mapping exercises. The card game posed a series of ideation prompts related to the Low-Tech development method combined with critical thinking prompts in the form of wildcards.

Figure 5. Low Tech Ideation Game in use

The workshop session was active, social, and provided a good atmosphere within the studio during the activities. All groups of students engaged well during the workshop and groups finished the session with a large volume of design ideas. When asked to reflect on the session students provided the following feedback.

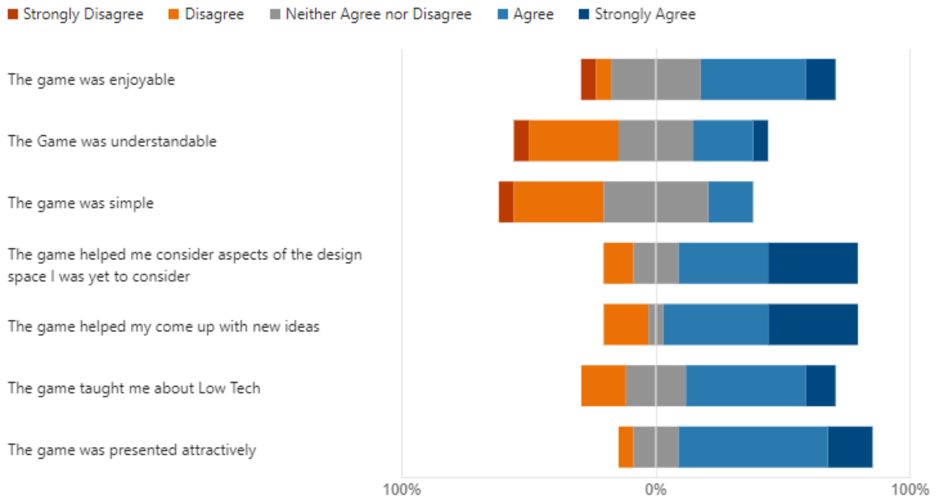

Figure 6. Feedback on the Ideation Card Game

Overall, the game was enjoyable but the nature of the game being a prototype was quite evident on the first play-through. Simplicity and understandability received low scores in the Likert response. Initially, the communication around the way the game was to be played was not understood and some groups struggled to understand that they were playing together as a team and not against each other. Additionally, it was found that unplayable hands could be dealt and as such new rules to allow teams to move forward when this happened had to be generated and explained on the fly. This is not surprising considering that it was the first time the game was being played.

The game was however successful in helping respondents consider alternative aspects of their design space, generate innovative ideas and teach some of the aspects of the Low-Tech method.

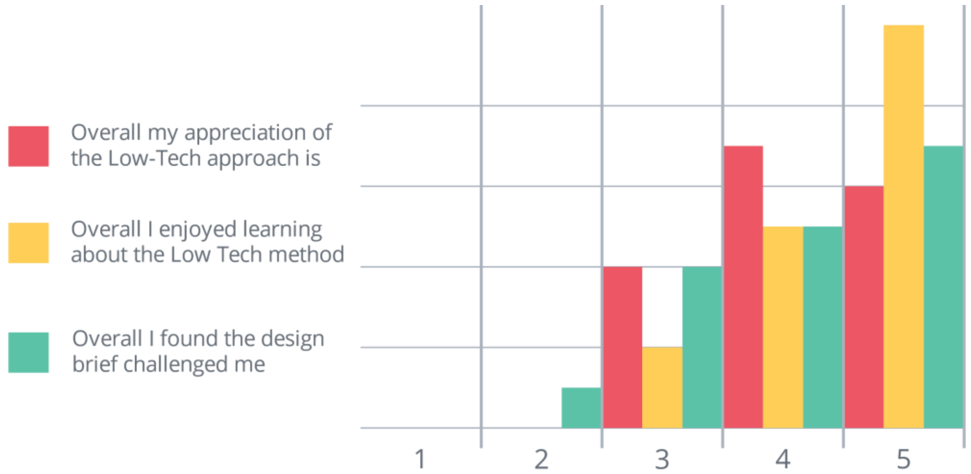

Figure 7. Feedback from respondents of the exit poll on their impressions of Low-Tech and the design brief

When asking respondents to rate their experience (5 being high or positive 1 being low or negative) most students found learning about Low Tech development to be an enjoyable activity with the majority having a positive appreciation of the theory. By and large, the design challenge was pitched at the right level. Although most students found it highly challenging, in anecdotal feedback nobody found the difficulty to be detrimental and design project outputs were, for the most part, an improvement on previous projects at this stage of the design education cycle.

4 DISCUSSION AND CONCLUSION

Overall, students' experience of the module was overwhelmingly positive and the quality of work that was produced during the class was to a high standard. Students felt that the approach taken was informative and their knowledge of topics related to design for sustainability increased.

Students judged that the methods used improved their comprehension of the more technical aspects of design for sustainability however the social elements were weaker. Within the Low-Tech Development model, the social aspects are a major theme so this should be addressed in future if a well-rounded education in the Low Tech is to be provided. One approach which is common within French-authored literature on the subject is the inclusion of a *territoire* within the design framework [9]. Due to the time constraints of the project, this was not an approach which was implemented within this version of the curriculum but based on the students' feedback it may be of great benefit in allowing students to focus on the social and societal elements of low-tech.

The workshop and card game proved useful to students but did not provide as an enjoyable experience as first intended. It achieved its aims of inspiring alternative approaches and questioning students' assumptions, but the implementation was awkward and at times confusing. Improvements can be made in the instructional material but overall, the rules would benefit from some simplification.

In general, the module achieved its goals of introducing students to Design for Sustainability ideas and the Low-Tech framework operated well within a product design context. All students were able to develop a product concept which involved a mechanical solution (and improved their competency in mechanism design).

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SPRINT TOWARD A SUSTAINABLE FUTURE

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ABSTRACT
Students of today should learn and see a need for change and recognize the importance of a shift towards a more sustainable business world, design and engineering is an important piece of this equation. The phenomenon of design and engineering is claimed to be in the complex domain. In the complex domain long-term plans are not predictable and the methods used to lead this process should be agile and cope with the emergent nature of the phenomenon. Short sprints pulled from a backlog is one of these methods and could therefore be argued to be relevant for teaching design and engineering students. In an attempt to learn and practice this method, the teaching of a design and engineering course at the master level is using this method directly in the teaching. Combined with the principle of "one piece flow" the students must every week prepare homework for their class, then followed by relevant classroom teaching and ending the day with a 3-hour graded sprint. The sprints are done either as an individual task or as a group task, depending on the learning objective. The students report less waste and higher learning effects, an impression also shared by the teachers. Let us sprint toward a sustainable future.

Keywords: Short sprints, "one piece flow"

1 INTRODUCTION
To solve a problem, it is an advantage to know what type of problem you are solving. A "wicked" problem is more complex than a "tame" problem [1]. Solving the climate change problem can be defined as a wicked problem [2]. Some of the core characteristics of a wicked problem is that there is no definite formulation for it, it has no stopping rule, the solution cannot be true or false, but good or bad, and every wicked problem can be a symptom of another problem [1]. An attitude taken at The University of Agder is that the students that we educate will have a very important role in becoming change leaders. It is of paramount importance for the future that they both see the need and learn of ways to work with it. A former employee of the author had a large campaign stating, "Standing still is not an option", this paper claims this metaphor applies to all businesses, all companies, and all persons, and can be directly aligned with the UN's 17 global goals. In terms of this paper, it might be climate goal thirteen, "Climate action" that becomes most relevant. We have to do something, but how do we take decisions and act to solve a complex problem in a complex context? According to Dave Snowden [3], you cannot analyse but only probe in the complex domain and have to decompose and then rebuild/construct when acting in a complex environment. This means that the agile [4] system Scrum [5] introduced first to the IT business should not be used in a complex system directly, it and other systems like Scrum should be decomposed and then rebuilt to probe for its usefulness in the complex domain [6]. One of the smaller components in a Scrum is a sprint, but its original 2-4 weeks duration has been challenged. It has been argued for an advantage to reduce it to 5 days, but not to make it shorter [7]. In this paper we argue for a further "decomposing" and test the effect of a 2-3 hour duration of "sprints" in education, we call them "Student sprints" in this paper.

2 METHOD & LIMITATIONS

2.1 Method
This paper is based on reasoning done in the conceptualization of theory and specific methods and testing of it in practice. The reflections and learning are done both as a teacher, but also based on formal and informal feedback. The formal feedback from the students has been done both by standardized mid-

term evaluation reports, evaluation of the progress in an oral exam and an evaluation done by a specific questionnaire to increase the detailing of the student feedback.

2.2 Limitations

Using students' surveys and feedback as an indication of the success factors of using sprints, have some biases. An important limitation is that we cannot tell if they salute the sprints because it has become easier for them to prepare for a course. The same bias goes for me as a researcher because I am both the writer of this paper and the teacher of the course. A classical Rosenthal or Pygmalion effect, where I can unconsciously affect both the students and my grading according to my wish for this attempt to be successful.

3 THEORY AND CASE

The definition of a Student sprint is taken from the method of Scrum [8], but also inspired by a former Tesla employee, Joe Justice's statements on how work is organized into small tasks and teams within Tesla. We, therefore, want to present a reflection on the theory in original sprints, but also the theory behind the student "sprints" this paper wants to share reflections on.

3.1 Agile, Scrum, and Backlog

Jeff Sutherland and Ken Schwaber are the creators of the Scrum system [8] , and were also part of the team coining the Agile Manifesto with its 12 agile principles in 2001 that has later been announced to be the original principles representing an agile mindset that started a lean inspired agile movement in IT and software development. In several agile methods, a backlog represents what is currently identified to be left to do in the project. In an ideal world the backlog could be a comprehensive list of items that should be solved, but agile is often used in contexts where maturity, learning, and problems might emerge and develop. In these settings, often related to complex problems, the accuracy of the backlog will differ. In some projects the team might try to make a comprehensive list, in others, it is considered wasteful to make such a list, where at best only milestones are made and or the backlog are only detailed in a short perspective, and the nearest timeframe. Normally there is at least made ready and prioritized list of items that are presumed to be the content of the sprint before it starts.

3.2 Original sprints

Jeff Sutherland acknowledges the Media Labs team's mandatory presentation every three weeks in the 1990s as an inspiration for the later sprints. The name sprints were according to Jeff Sutherland chosen to show a sense of urgency and high pace before feedback is given [5]. When entering a sprint, the team must commit to a clear outcome of the sprint. One of the original 12 agile principles [4] states "Working software is the primary measure of progress", the need to create something "working" is enhanced with Lean Startup [9] and its focus on Minimal Viable Products (MVP) [10]. So, the clear goal in a sprint is often challenged into making something that the customer or representative of the customer can test and give feedback to. Here is a list of some of the other theoretical arguments for conducting an original sprint:

- A sprint should have a clear and defined goal and be limited within a predefined time frame (A timebox).
- A sprint team is normally also predefined in the sprint and should ideally consist of 7 people plus or minus 2 with cross-functional competence. A small team is preferred due to the exponential growth in direct communication lines in larger teams.
- A working team within a sprint should not be presented with new elements to solve during a sprint. They should only be supported with any request they have that emerges within the sprint that has to do with solving the original goal of the sprint.
- The teams should be autonomous in how they reach the goal. There should be 0% excuses for not reaching the intended goal.

Dealing with a complex problem or project, a sprint takes a part of the problem or project and puts it into a manageable size. This simplification together with a clear predefined goal gives the teamwork peace and enables concentration.

3.3 Design sprints

It is claimed that the Design Sprints [7,11] have been inspired by design thinking to reduce its timebox from 2-4 weeks to 5 days duration [7,11]. A sprint of fewer than 5 days duration is not recommended, due to practical concerns with facilitation [7,11]

3.4 Student sprints

The development of the Student sprints has taken inspiration both from the method of Scrum [12], but also inspired by a former Tesla employee, Joe Justice's statements on how work is organized into small tasks and teams within Tesla. The main inspiration came from a YouTube interview with Joe Justice [13] where he stated that Tesla has learning cycles every 3 hours. The sprints started the same day that the course started, and the students that answered the questionnaire reported that 86% did not attend the first sprint, the next week 97% attended and for all the following weeks they all attended. This is the opposite trend that many teachers report from their classes, where fewer and fewer students attend class as the subject progresses.

The Student sprints are graded, and thorough feedback is given to let the student reflect on where and what they have the potential to be better at and what they have understood. All the sprints make up the whole delivery of a mandatory project report that counts for 60% of the grading in the subject. This means that if they pass all the sprints and are happy with the level they have achieved they can get a weighted grade and do not need to do any extra work for when delivering the final report. If they want to improve their grade they get a similar task they have to answer as a compensation for the sprints they want to improve. In a way, this means they can "cherry-pick" their weak points. That is correct, but isn't that what we want the students to do? Improve where they have knowledge gaps. When they redo a sprint with a new task, the grading expects a higher level of understanding and perfection. Because the maturity level is expected to rise, and also the time they can spend on answering this is not limited to being within a timebox.

Here are some examples of the sprint content with their logic/dependencies:

1. Students are divided into groups of 4 people that have to prepare to read an academic paper within the curriculum as preparation before the lecture and sprint. They have to write their own personal takeaway of the content as a "pass" to enter the group before the sprint. The papers have either been referenced or part of a previous lecture or are the content of the lecture they are entering. When the sprint starts they are given 2,5 hours to prepare a video presentation of the content that should be delivered in a format that their fellow students understand.
2. In the following sprint they had to read another paper. But not knowing how the sprint was they might have expected another presentation, but this time they had to see the students' video made of the paper the week before and make peer review feedback to the student group that had created the video.
3. In another sprint they were divided into groups of 4 and had to prepare some readings on an overall understanding of the subject, but when the sprint started they got to know that it had been a pre-booked podcast appointment with a number of designers/developers and engineers from the business they study to become a part of.

In many aspects, you can say that it is a 3-hour test every week, but there is a difference in how we think about it; First, the sprints are mainly organized as a team effort. The reasoning behind this is that we believe learning among students is much greater as a team rather than doing individual work. We are not doing it because we want to grade the students, we do it because we want them to learn. The grading is only done as a part of feedback, but also to let the students feel that they lose something if they are not attending. We could have made the sprints mandatory, but that would have made the system less flexible. The sprints are not mandatory, and they can as mentioned choose to write a similar task as a part of the project report. If a normal mandatory task would be presented as a group work for the students, procrastination might kick in on all levels. Not preparing before lecture, not paying attention to the lecture that much, since they think they can read the notes later. A sprint can also be built on a previous sprint that often enables more learning and becomes a representation of "continuous improvement". In a test the accessibility of tools is often limited, in a sprint all available tools are welcomed. Even the advantages and limitations of AI (Ex. Chat GPT) have been tested in some of the sprints. A sprint also differs from a test where a test often have to prepare the students on what is going to be asked, in a sprint we give them preparation material but do not need to prepare them on anything about the content of the test. We do this to not let the students be selective on what they are reading and learning. Live streaming of the lectures was shut off after the first year of testing sprints. The reason is both argued in organizational challenges, but also the power of meeting people physically at Campus. An attitude is taken that “It is better to get a student from home to socialize in class, than to help a student that is not attending to learn from home”. The stand is taken because one of the most important skill sets that a physical Campus can teach students is teamwork and interaction between people. To have sprints both physical and digital in parallel have hence been tested and it is definitely manageable, but the attendance in class and at Campus suffer if streaming is made available.

3.5 The difference from a task

The novelty of using a sprint might not be too obvious from dividing the course into tasks, but the advantage of rather using a sprint lies in the details. We have a tendency to measure students' performance in how well their results become in that task. Because their grades become so important for their future careers their goal is more about getting the grades and not getting knowledge. Even teachers believe that a student that has been drilled to solve specific national tests is a better student just because the test result is better, even though they are comparing themselves with students that have not been given any specific training for the test form of the national tests. The main reason for using sprints is to focus on the effort and process and not only the result. Therefore, a big point in the sprints is not to reveal their content until both homework and lectures are done.

3.6 The difference from a test

Since the sprints are mostly being graded the similarities to weekly tests are notable. They are both based on pushing homework and attention in class in order to achieve a good grade and having a timebox for delivery, the content is not revealed until they start, and they both are being graded. So, a weekly test and a sprint can in many ways be the same, but it is the practical difference in use that makes the difference. A test is a measurement for control and its purpose is closely linked to being a tool for measurement, while in nature a sprint is a practical way of making something that can be tested. In other words, the sprint can and should be a practical task and it is even better if the tasks can build on each other to become a project. Many of the sprints have an effort-based evaluation and not a result-based evaluation as most tests have. The sprints can and should be organized as group work where this can enhance learning and if the groups are internally motivated grading is not needed, but a thorough feedback and improvement suggestions should be prioritized. So even though the difference between a sprint and a test is subtle, their original purpose is different. A sprint is being used as an agile work session tool in business, while in business a test is used in order to measure performance already done. Learning and development through working together is the essence of a sprint, while a test is often a measurement of the progress within a topic so far.

3.7 The principle of “one piece flow”

The thinking behind the use of sprints is linked to the theory, effects, and experience of practical use of the principle of “one piece flow”. This can again be linked to the effects of the problems related to multitasking ([14,15]) and how good habits often happen in a short time span, with incremental changes [16]. “One piece flow” does not only apply to the short sprints but also how the subject encourages the students to not think about the subject in between other subjects. Students are encouraged to practice “one piece flow” with the following routine; 1. Do homework in the time period directly before the lecture starts, for most students this means the evening before the course starts. 2. Be present in the lecture and link it to the homework and practical examples. 3. Attend the sprint and deliver a result before the timebox is over.

4 RESULT & DISCUSSION

4.1 Advantages

The questionnaire that was sent out among the students about using sprint as a part of the topic, when this paper was written it only had a feedback rate of 34% with around 30 respondents. 67% reported that they have increased their preparation before lectures, 71% say it increases their attendance to the lectures and 76% says it has increased their attention level in the lectures as a direct consequence of using splints as part of the lectures.

The group sizes are different from many sprints. Mixing the groups from sprint to sprint makes the social networking among students higher. Still, they are organized into core groups of 4 people in order to give them some stability in about half of the sprints. Types 1 and 3 of the sprints are mentioned under point 3.3. were the sprints that the students reported they had learned the most from. The principle of having a timebox in order to set an artificial deadline for a task to push forward a result was the principle 63% of the students felt was the primary effect shown within a sprint. The effect of a backlog (12%) and an enclosed container (16%) was not that easily recognized. Only 8% reported they had not learned any of the mentioned effects of a sprint. A positive effect of a sprint is reported to be that it is much easier for the students to organize the meeting and start working together. They also report that the pressure of delivering helps them to do exactly that and not procrastinate a task. Some of the students report that having parts of the grading done every week also motivates them because it becomes a measurement of progress and how much of the grading has been done. An important part of using the sprints is that Scrum and the use of sprints is part of the curriculum, and their hands-on knowledge about being organized within sprints creates a practical learning experience.

4.2 Disadvantages

By grading the sprints, the first sprints are being graded on a low maturity level in the subject. That is being taken into account when the sprints are graded, but to avoid “inflation” of good grades, the first sprints are in a much smaller percentage, than the latest sprints.

A negative side of a sprint is that it can be stressful when the sprint is conducted. Some students would like to study more, and work more than the sprint allows after the sprint has started. In a way, we align the students' effort with a sprint, but their preparations for homework before the sprint still differ. The procrastination of homework, preparation, group work and even paying attention in class is only possible within the deadlines if you want to join the sprint if you want to prepare for a good execution of the sprint.

If someone is sick or not able to attend that day they will suffer for not being given any feedback on their progress. One of the sprints conducted was too ambitious in their goal and none of the students did manage to fulfil the rule of always delivering the goal . This sprint taught some of the students the importance of specifying the goal and the need for thorough preparations before a sprint, but it was not a good way of conducting a sprint in general. This was the only time a sprint was made with too high ambitions to actually make a delivery, and this is also the sprint the students reported to have the lowest degree of learning in. A too short timeframe might hinder the quality of the delivery and some students find that the sprint should be a bit longer in order to deliver better quality. But no one reports the actual sprints to be too short, 8% even want it to be shorter. With a response that 92% find a 2,5-3 hour sprint to be accurate in time the duration of the sprints will not be changed in the nearest future. Some of the students report that they understand that the sprints are under continuous improvement, and they find some of the attempts to be less accurate. As a teacher, I can confirm that some of the sprints are run almost as tests of the limitations of the content in a sprint. The sprint that failed to meet its ambitions was organized using the programming/coding functions from ChatGPT and the groups should within the sprint organize themself both in teams of 4 but should also deliver results to a more skilled team that could evaluate the code being generated. The scope of the sprint was not clear enough and the preparation for the skilled time was not good enough, so it ended with not delivering a workable solution. But many of the students reported learning from failure and saw the importance of well-defined sprint goals.

4.3 Improvements

The students want to be prepared with all practical and technical tools before the sprint starts. If the sprint contains video editing, they should be able to know this in advance so that the technical part of the presentation does not become a bottleneck for showing their subject skills. This is a very just demand and should be fixed.

The preparations for the sprints can be announced as soon as possible and could even be announced on a longer time span. Since the groups are changing

One of the early sprints almost failed because it had the ambition to create self-organized teams around a common task. It was about using programming skills in combination with ChatGPT as a tool to solve a design process. This became too complicated and even though some reported a new insight into the complexity of organizing a design task, it should have been prepared more thoroughly.

For the teacher, the time spent on feedback increases, and with over 90 students per semester the time spent every week is a bit higher than stipulated. Some of this work burden can be reduced with peer review, somewhat larger groups reversed classrooms, etc.

5 CONCLUSIONS

With the number of students attending class after the sprint was introduced as a method there is a claim that the negative effects of missing out if you do not attend overgoes the positive effects of a social learning environment that happens when all students that are capable of attending do so physically. There is an assumption rising that the sprint method would give value to many forms of teaching and especially in this course where teaching the sprint method is part of the mandatory syllabus. This gives the students a direct knowledge of the method, so even the bad sides of the method give them insights. Sprints in a short timespan are especially relevant for problems in the complex domain, where you can only probe and then sense what your next response should be. Based on the feedback from the students, the knowledge level they gain through the course, and the attendance in class I will continue using sprints and testing agile methods as part of the education method and have a firm belief that it makes the students learning higher and that less waste is used on organizing and non-value-adding activities related to knowledge gain.

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PARTICIPATORY APPROACHES AS DRIVERS FOR SUSTAINABLE WASTE MANAGEMENT IN RURAL NEPAL

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ABSTRACT
Nepal has been facing waste management (WM) problems for many years, especially in cities, but also increasingly in rural areas. Improper treatment, lack of organisation and management of solid waste (SW) contributes to pollution and toxic emissions, which inflict harm to humans and the environment. This study discusses how solid waste management systems (SWMS) in rural areas of Nepal can be improved. Rural regions are dealing with profound sustainability challenges, among others rapid expansion of tourism and fast changing infrastructure. The theoretical part discusses SWMS terminology both on a general basis and in rural mountainous regions, where the practical part covers a case study with design concept and practices. Literature shows deficiencies of the entire SWMS in Nepal, for example in form of inadequate communication between the government and local stakeholders, including the lack of participation possibilities. This problem is met by applying a participatory design approach (PA) for designing a waste bin with local stakeholders in Lower Mustang, Annapurna Region, Nepal. The didactic aim of the study was to train design students to work in different countries. The project is part of a Nepal – Norway collaboration (SAMAJ – Transdisciplinary Education for a Sustainable Society) which exchanges Master students from design and planning from both countries.

Keywords: Solid waste management systems, participatory approach, stakeholder collaboration, rural mountainous area Nepal

1 INTRODUCTION
Currently, over 30 million people live in Nepal. The growth rate throughout the country is increasing rapidly, where 4 out of 5 people live in rural areas [1]. Before the outbreak of Covid-19, a sector analysis estimated that Nepal received over 1.17 million international tourists in the year of 2018. The most popular reasons for visiting are trekking, pilgrimage, mountaineering and leisure [2]. The large number of visitors have led to severe challenges for SWMS. Literature shows that rural areas with a high tourism rate are more vulnerable to be compromised by improper treatment of SWM [3]. Poorly managed infrastructure, technical support, finance, and lack of communication are some of the ongoing issues. Overfilled containers and landfills, including the lack of bins, contribute to the problem of littering and improper treatment of SWMS.
The following article discusses theory and practice to meet SWM in rural areas with a special focus on PA. Chapter 2 briefly addresses SWMS as a national issue in Nepal and presents background, policies, and SWM in the country. Chapter 3 explains challenges of tourism in rural areas of Nepal, while chapter 4 introduces the case study area. Chapter 5 presents the application of PA in the project with the design development. Design development, results and outcome of the waste bin is described in chapter 6. The concluding remarks in chapter 7 summarise the reflection from the first author, where chapter 8 present benefits and challenges in training students to work in diverse cultural settings by the second author. The case study that is represented in this paper is based on a review article and a design project report from 2022, undertaken by a singular student from the Industrial Design Course over a period of 5 weeks exchange to Nepal. A Master Thesis (MA) with continuation of the project is currently undertaken by the same student and first author, which is expected to be completed by June 2023. Comprehensive and selected parts form the project report and some details from the MA is therefore presented. Results,

design development, refinement, final product, PA sessions and extended material from the MA is therefore not detailed elaborated in this paper.

2 SOLID WASTE MANAGEMENT ISSUES

Municipal Solid Waste (MSW) and tourism waste (TW) in urban and rural areas are stated as a global sustainability issue. Improper treatment and disposal of SW can cause a range of issues. It can become a financial and economic threat and lead to environmental challenges [4]. Pecci, (2017) states that every landfill will eventually leak and contaminate the surroundings [5].

A strategic report from the World Bank (2021) estimates that Nepal generates 1.7 million tons of MSW annually, where over half of it is biodegradable waste [6]. In 2011 the Government of Nepal authorised the SWM Act 2068, where it is the government's responsibility to manage SW efficiently and systematically [7]. The act includes creating a healthy and clean environment by using the 3R's principle: reduce, reuse and recycle. However, research has revealed that this act has not been carried out and the strategy has failed. The issues occur in several stages, such as segregation at source, waste collection and transportation, waste processing, disposal, formal and informal recycling [8]. Academia, practitioners and local residents have suggested and even demanded changes to the current SWM strategy [9].

Burning waste, dumping waste at landfills or in rivers are according to CBS (2021) the three main SWM methods in Nepal, with the first method being the operating one in Muktinath [10].

3 TOURIST WASTE IN LOWER MUSTANG

Nepal offers a diverse landscape, wildlife and attractions that create great opportunities for the tourism sector. However, TW impacts the environment and generates more pollution, which creates a strain within the entire SWMS [11]. Hotels, shops, transportation, and other services contribute to increasing SW. Plastic bottles, cardboard and paper, food waste, containers and packaging are the most common components of TW in rural areas. Transferring stations, bus stops, parking spots and other tourist attractions have an increase of biodegradable and non-biodegradable SW [12].

The new waste bin aims to be installed at the transferring station in Muktinath. Members of the local committee including Muktinath' s two head chiefs decided in 2023 during a project presentation to start with the collection of one waste material. Results from field visits and material collection indicates that the most disposed item is plastic bottles, hence the proposed design solution is aimed to collect this material. Representatives from the village have requested a design solution that can be utilized and adapted for future expansions where a collection of separate units can be added to collect a range of different waste materials.

4 CASE STUDY INTRODUCTION

The case study and design intervention took place in Lower Mustang, located between the Tibetan Plateau in the North and South of the high Himalayan Mountains. Specific focus was on Ranipauwa, a village within the Mustang district. Ranipauwa is a hub for both trekkers and pilgrims as the famous Annapurna Circuit trek runs around the Annapurna-Himal. Trekkers and pilgrims generate income for the local residents, simultaneously the SW problems increase as shown in Figure 1.

Different design methods and tools were applied to discover, refine, understand, and define SWM issues in the village, including the development of a design concept by applying PA. Figure 2 shows the design phases from the 2022 project report, where Figure 3 shows the different methods and tools that were utilised in the project. The aim of applying PA as the main method is to meet the user's needs, generate ownership and facilitate empowerment to the involved stakeholders [13]. Creating overall ownership of the design is one of the most important aspects in PA, while participating in the design process fosters inclusiveness. The design and PA process are further described in the next chapter.

Figure 1. Waste Pit in the Ranipauwa village

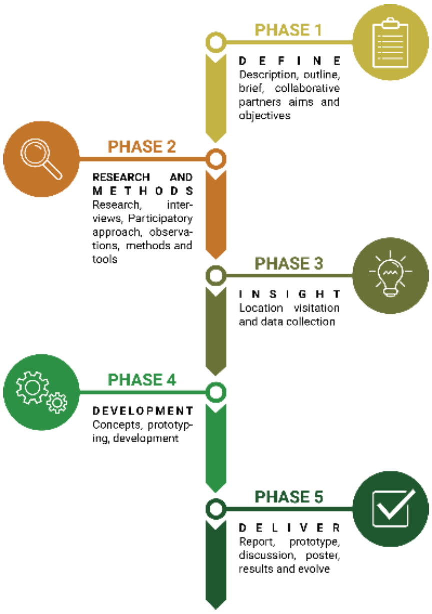

Figure 2. Design Phases, (left). Figure 3. Applied design methods and tools, (right)

5 PARTICPATORY INTERVENTIONS

All participants that are affected by the design, such as local residents and stakeholders, were invited to be involved in the project at different stages. PA is a broad term that involves different approaches and methods, where inclusiveness, empowerment and communication are centralised in the process. By involving stakeholders into the design process an alignment of joint contribution is formed [14].

As part of the PA, formal and informal interviews where individual or group sessions were conducted. The aim was to gather insight about the current situation and to develop design concepts. Figure 4 shows one of the PA sessions where a representative from the mother's group evaluates provided materials. Figure 6 shows a group of local residents that participated in the project.

A design wishes, demands and requirement (WDR) list for the design features was developed based on feedback, interviews, surveys, questionaries, field visits and observations. The input from the local stakeholders provides guidance and knowledge about the surroundings, end users, collection systems, special needs, weather conditions e.g., which further leads to a sustainable solution. In this case a sustainable solution is not necessarily a fancy high-tech waste bin product, but rather a realistic, affordable and long-lasting product that aims to fit both the current situation and the possibilities of future expansions.

A conceptual design was developed based on the WDR list and in collaborations with stakeholders during the project. The first conceptual design is seen in figure 6. Design justification for this concept is excluded in this paper as it is the first idea and not the final design solution.

Figure 4. Mother's group representative, (left). Figure 5. PA session with residents, (right)

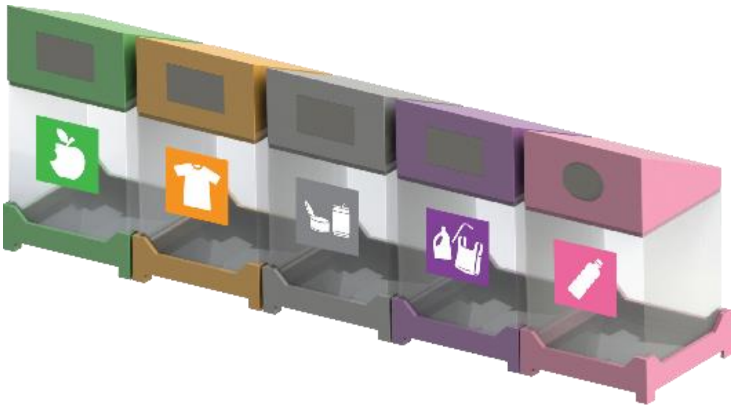

Figure 6. First design concept

6 DESIGN DEVLOPMENT AND RESULTS

The design development is adjusted and refined during the MA project. Several PA sessions with stakeholders have been carried out with great results, such as installing a 1:1 functional prototype in Muktinath. In addition, a PA session with a group of voluntary participants that represented the consumers were executed. A larger survey revolving graphical design content such as waste symbol icons and colour preference was performed during the MA, resulting in statistics about the most preferred waste symbol and colour. A proposed illustration of the product with separation of different waste materials is seen in figure 7. The design is based on multiple PA sessions, a WDR list, testing sessions, prototyping and refinement. A selection and summarised collection from the WDR list are seen in figure 8. A full and descriptive WDR list will be provided in the MA and possibly published online after the submission in 2023. It is advised to keep in mind that the design is aimed for rural areas and not developed countries. Figure 9 shows a 1:1 functional prototype, installed in Muktinath. Feedback collection, observation, testing and interviews were further executed. Inner waste bin bags are developed and designed based on local materials which can be recycled and reused. Collection method and retrieval of the waste is developed for easy collection. The infographic is designed to be self-explanatory, easy to understand regardless of nationality or language. It is also designed based on inspiring the consumers to compress the waste before disposal. This improves the amount of waste that can be collected and contributes to improved waste volume that can be stored in a storage unit before being sold or transported to external actors.

Figure 7. Proposed material collection and final waste bin design

Specification and feature	Justification
Fully enclosed compartment.	Avoid direct waste burning in the bin. Offer safe protection of collected waste.
Manufacturing cost cannot extend 20000 NPR pr. Unit.	Parts are designed with necessary materials and features.
The final product/material/parts must be suitable for transport including flat-packed options and be easy to assemble.	Transportation on dangerous and off-roads requires easy transport of materials or product parts.
Materials must be made with long-term sustainability features or coating.	Materials with long durability, low-militance, can withhold extreme elements and weather exposure is recommended.
The product must be self-explanatory, consumer friendly and inclusive.	Waste symbol/icon, colour recognition and infographic features are designed to be readable regardless of language barrier.
The product must offer expansion possibility of material collection.	Colour adaption, adjustable waste retrieval opening, and unified size is offered.

Figure 8. A WDR selection, (left). Figure 9. Installed functional 1:1 prototype, (right)

7 REFLECTIONS

Conducting PA in the field provides a deeper understanding of the current issues in rural areas of Nepal. The application of PA as primary research offers hard data that has not been processed by a second or third-party and provides substantial results. Collecting data, facilitating, advising, providing essential information and education are roles of the design student. Including providing a safe, trustworthy, reliable and inspiring environment for the participants. According to research, including PA in the design process offers a range of possibilities which contributes to a sustainable design solution. The design outcome is based on being a long-term solution for a specific rural location, whilst being adaptable and expandable to other rural regions of Nepal.

Parts of the design process revolved around advisement of feasible solutions to withhold the goal of being a sustainable design. Language barriers were a great challenge especially during the consultant session. Another challenge during the project was a reluctance to commit economically to improve the current SWMS, resolving in challenges of contribution and involvement from local actors. Being able to adapt and find creative solutions to these types of challenges is vital to sustain involvement, inclusiveness, empowerment, engagement and contribution to improvements. As a student reflection, PA is considered as one of the most valuable and important factors to provide a sustainable solution that fit a specific target group, location and withholds strict design requirements. Training and education were provided to certain groups revolving manufacture, maintenance, design assembly and waste collection. Additional advice regards separation, retrieval, safe storage unit expansions, transportation, waste value, places to sell the sorted waste, how to avoid and reduce waste burning, how to educate a larger consumer group, including education for local residents, was provided during PA sessions with the representative participants from the Ranipauwa village. This was executed as an addition and expansion of the project as the topic was highly relatable for what occurs to the waste after retrieval.

Continued collaboration with local residents and stakeholders is recommended to raise motivation for long-term improvements and to increase their sense of autonomy. It is important that they can contribute with local attributes to these types of projects as it shows a willingness for improved environmental care, even if the current systems are lacking. Respecting and preserving cultural preferences and norms should be equally valuable. It should not be an aim to implement existing solutions found in other places, but rather to design a concept that is right for the rural areas of Nepal in contribution with the residents. Through PA a sustainable waste bin has been developed and installed in Muktinath.

8 CONCLUDING REMARKS

The goal of SAMAJ is to meet the SDGs with help of sustainable design for everyday in various cultural contexts. Applying insights from design theory in real-life allows students to apply and test participatory design methods, and experience how outcomes can vary. The findings of this article are practically implemented in a case study and project designing a sustainable WM solution. When designing for people in developing countries, design students can develop realistic expectations. Building relationships requires time, which is necessary to gain profound insights into stakeholders' and users' needs, and in local culture, values and traditions. This attempt is often acknowledged in a project, where participants report to feel empowered and heard, which in turn might increase their motivation to contribute. In this way, design for developing countries, educates 'reflective practitioners' [15] rather than mere 'problem-solvers'. 'Reflective practitioners' are characterised by achieving a balance between a design-led and research-led processes and between desirable, feasible and viable solutions [16].

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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DEMOCRATISING VIRTUAL REALITY WITH CRITICAL PEDAGOGY, DESIGN AND MAKING

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ABSTRACT
This article narrates the work in an undergraduate first-year project-based industrial design studio subject that started with unprecedented students' isolation in the Covid-19 pandemic. It focused on user experience and the exploration to democratize new technologies, such as virtual reality, with the design, development, and testing of three degrees of freedom controllers, interfaces, and games. The project was based on critical pedagogy, design and making. Heuristics promoted an evolutionary process of experimentation and testing with no fear of failure. A gaming approach promoted the learning of coding and trialling through play. E-Portfolios helped students to develop their own autoethnography and critical assessment. Students' Feedback on Subject surveys showed that the subject is popular among them. They finalized their semester analysing their designs and user experience by playing individually and against each other with their controller and game working prototypes. Two years on and back to face-to-face delivery on campus, outcomes might enlighten readers as these demonstrate reliability that survived the challenge of Covid-19 lockdowns and show strengths and shortcomings relating to our new digital-physical reality in education and the profession. As participants, students understood that their projects fitted to a more significant research framework where the authors intend to facilitate collaboration, co-habitation, and sustainability, to augment human intelligence through the exploration of extended realities and human-computer interaction, and to innovate traditional design process, that is ideally concurrent but mostly sequential, in today's scenario of globally distributed collaborations that are building new singularity workflows of simultaneous ideation, prototyping, testing, and production.

Keywords: Autoethnography, codesign, critical pedagogy, human-computer interaction, user experience, virtual reality

1 INTRODUCTION
This article narrates the work in an undergraduate first-year project-based industrial design studio subject with a cohort of 60 students experiencing unprecedented isolation in the Covid-19 pandemic. The pandemic was a big disruptor of the normal in society worldwide. In Australia, it also affected the way that higher education delivered its learning and teaching when the country closed its international borders from the 20th of March 2020 to the 1st of November 2021 and slowly accepted the arrival of international students and those who were stranded abroad from 2022. With no government support, universities had to make do without the influx of international students who represented a strong contributor to their financial sustainability and went into restructuring. Many academics either lost their jobs or were casualized. Paradoxically, that dramatic impact also materialized the long-unfulfilled promise that information and communication technologies (ICT) would facilitate learning and teaching. A more than 15 years strategy that intended to implement e-learning in Western Sydney University was realized in two weeks in March 2020 to also enable online teaching to our local students. They lived mainly in the working- and middle-class western suburbs of Sydney that had their livelihood threatened under strict lockdowns, restrictions on travel, number of people per room, police patrolling the streets and heavy fines that intended to stop the spread of the virus. These limitations were slowly lifted in 2022 but created animosity. This was a tale of two cities in one. The western suburbs under lockdowns contained the population with the highest level of above 80% vaccination in the state and struggled with $42 million of unpaid Covid-19 fines. While eastern suburbs, where the pandemic started in Australia and did not experience lockdowns or restrictions, only reached 35% of vaccination in 2022 [1–4].

2 PROBLEM STATEMENT

The first author was given coordination of the first-year subject called *Designing for User Experience* in the spring of 2021. The challenge was, how to run individual applied design studio projects in industrial design education in a way capable to overcome the abnormal conditions presented by Covid-19 restrictions. As per the pre-approved template for the subject, the expectation was to deliver it face-to-face and have access to equipment and tools in our in-campus workshop as the means for *"creating strong emotional, sensorial, and functional connections essential in supporting inclusive design, engaged usability, and high-quality human-centred experiences when delivering successful products and services."* Informal views were that the previous year's students' learning experience was affected by Covid-19 restrictions. They were able to mostly do ideation and conceptualization and some modelling depending on a courier service between their home and the university's workshop (e.g., low-resolution 3D printing). However, there was no indication of full proof of concept, working prototypes and product, system and end-user experience testing at the end of it.

3 METHODOLOGIES

Normally, first-year projects are greatly teacher-centred with a controlled master-apprentice transmission approach. In our industrial design and design technology courses, students generally are high-school leavers who do not have a background in applied arts and are not savvy in the use of manual and electrical tools in a design workshop. The unusual circumstances for the subject during the Covid-19 pandemic required ingenuity to achieve the approved template since there was no way to control individual work, materials, and their use in each student's home. A reversal from transactional to transformational methodology was developed based on our Generation Z students who are characterized as digital natives comfortable with the use of the Internet, portable digital devices, and social media. Freire's [5] [6] critical pedagogy was used to propose the subject as a design research one to empower students' ownership. Their projects became a process of autoethnography, visual ethnography and action research where the apprentice was the master and the lecturer a moderator in the process of learning and generation of new knowledge. In those terms, the production of a product and its eco-system were the means for both, a critical design [7] to challenge assumptions, increase social and cultural awareness, and create discussion, and new ways of thinking, and a critical making [8,9] as a process of reflection and learning through hands-on productive actions that link physical and digital technologies for conceptual, prototype and user experience explorations.

4 METHODS

4.1 Technology

Online Zoom teaching became the predominant option to deliver classes from 2020 onwards in our university. There was even a risk of fines for staff and students who drove to campus in case they lived outside a suburb. Within these limitations, a clear challenge was proposed to gather students' Generation Z interest: *Resolving digital and physical gaps for virtual reality (VR),* which this time was in the form of a Three Degrees of Freedom (3DoF) VR controller. True to critical pedagogy, another option for students to create an AUD $70 to AUD $100 VR headset was discussed but was left aside for later work with more advanced students. The current cohort had no electrical engineering, model making and programming skills yet. The lecturer explained that VR is defined by its freedom of movement and interaction. VR with Six Degrees of Freedom (6DoF), like Quest 2 Pro, is totally immersive and works with controllers that allow movement in six spatial axes. Three main axes are translational and the other three secondary that are rotational. 3DoF only allows users to move in three axes, X, Y and Z (look left and right, look up and down, pivot and right).

The gap in the market was to produce a 3DoF controller that allowed users more movement, interaction with artefacts, other personas and environments, teleporting, selection of objects, experiencing gravity and physics, etc. The reason to work with 3DoF was also about access and cost. The 80-year-old undelivered forecast on the benefits of VR for all would only be possible if we made it accessible to everybody on their mobile phones and with a cost as inexpensive as the one of a social media app. There were signs that technology was moving that way when Asian mobile phone companies revealed their plan to include VR in their mobile phone plans (Singapore, South Korea). The task for the students was to research and find a solution with as small amount of money as possible with their mobile phones, free and open-source software (FOSS), free Unity3D scripting, a minimum investment in Arduino equipment and either a Google Cardboard (cost between AUD $5 to AUD $40 in eBay) or a second-hand VR headset. The lecturer provided links for the cheapest headsets available in Sydney ready for shipping and presented a demonstration via Zoom and his iPhone mounted in a Zeiss VR ONE Plus headset bought from a local EB Games shop for AUD $19. Several students said to be excited about the project since they were already familiar with mobile games, or they were "old" gamers who had 3DoF VR headsets in their homes.

4.2 Curriculum

Student projects were helped by a new interpretation of the three assessments approved in the subject template. Previously, Assessment 1 was about sketching ideas for a new wearable design while Assessment 2 was a report (500 words) and three A3 posters with illustrated concepts on material selection, finish, technology, and wearability. Assessment 3 was a report (1,500 words) and one presentation on an A3 final proposal poster. From 2021, all assessments were converted to applied projects powered through critical design and critical making. Submissions were required via individual Turnitin and ePortfolio process diaries. The aim was to achieve a desirable, feasible, viable, and tested Product Value Proposition (PVP) developed as a finished working prototype also known as Minimum Viable Product (MVP) ready to play with it and to show how the design operates and how realistic its implementation can be. Human-centred design (HCD), user experience (UX), design thinking, and other similar methods complemented each other in three phases:

- Assessment 1 Scope and User Research (Week 4): An audit with annotations on direct UX through experimentation (Figures 1, 2) with up to five devices already available at home (e.g., mouse, keyboard, Xbox, Nintendo controller, Luna controller, Sony DualShock, Logitech F310) and tweaked to work with VR thanks to FOSS or inexpensive software (e.g., RiFCAT, vVRy, ALVR).
- Assessment 2 Ideation and Testing (Week 9): As a phase for designing, exploring, experimenting, and analysing results, failures, and amendments of several low fidelity to rough working prototypes (Figures 3, 4). Working with basic Arduino and Unity3D benefited from the self-learning exercises that started from the first week of the semester and the weekly support of the tutor (programming) and the lecturer (HCD, IxD).
- Assessment 3 Build Launch and Measure (Week 14): As a final stage for implementing, developing, operating, launching, and analysing the final high-fidelity MVP and PVP working prototype, students' user experience reflections and recommendations on their projects and the subject, and their projections and recommendations for the design as if they had to continue with their projects to reach manufacturing and commercialization stage (Figures 5 - 8). Assessment 3 included a Pecha Kucha pitch presentation that required self-evaluation.

4.3 Autoethnography, visual ethnography and action research

Critical pedagogy, design and making required tools to allow students to keep track of their work, in contact with each other, and the lecturers. Covid-19 isolation had reduced contact to two hours of live synchronous Zoom tutorials per week and asynchronous uploads to an LMS Blackboard subject repository (e.g., recorded lectures, announcements, instruction, digital materials, scripts, links, interactive games, interviews). The lecturer promoted the use of MyKnowledge Map (MKM) ePortfolio as a key tool for individual design process diaries. The tool was offered on trial by the Pro-Vice Chancellor Learning and Teaching Office which looked for exemplars to implement ePortfolio later in the university as part of its 21st Century Transformational Curriculum and Learning Futures strategies.

The value of the MKM ePortfolio was that it was an easy tool for combining autoethnography, visual ethnography and action research. These three types of annotation, reflection, and interpretation (*graphy*) complemented each other. Autoethnography [10] was simultaneously an ePortfolio method, a process, and a product that treated research as a socially conscious act. It showed self-reflective research to describe and systematically analyse personal experiences (*auto*) as the means to understand other people's behaviours as cultural experiences (*ethno*). The visual ethnography [11] was important since the participants were design students. Visualizations and their analysis are vital for their training. This was a research method that brought theory and practices together to get to know and interpret photographic, film and video recordings and annotations in an iterative cycle from observation to generation and communication of experiences. Action research [12] completed that process of critical design and critical making simultaneously facilitating the investigation and resolution of issues. This

was very important since the projects involved a lot of discussions and figuring out how the designs needed to evolve in both the physical and the 3D semi-immersive environments.
In practice, the MKM ePortfolio comprised weekly updates on tasks carried out by students individually and as a group. They were able to share their MKM ePortfolio as progress reports for discussions with the lecturer and other students in and outside the live Zoom sessions. Their learning of design and making was also assisted with additional tools that were later imported to MKM ePortfolio. For instance, exploration via YouTube video recordings and MIRO boards allowed synchronous and asynchronous individual and group work based on structured sets of UX templates for iterative analysis of data and observations as students progressed from Assessment 1 to 3 (e.g., concept modelling, empathy mapping, user persona, journey maps, taxonomies, affinity maps, UX and ePortfolio Checklists). Notably, students assessed weekly each result on what good progress was or needed to improve and develop further. A Four Sights Strategy especially prepared for the subject helped students to articulate whether previous assumptions on work and experiences were validated after testing them (backsight), what was the benchmark set by their counterparts and the industry (cross-sight), where were they based on their backsight and cross-sight observations (insight) and how and what did they need to do next for their projects next (foresight).

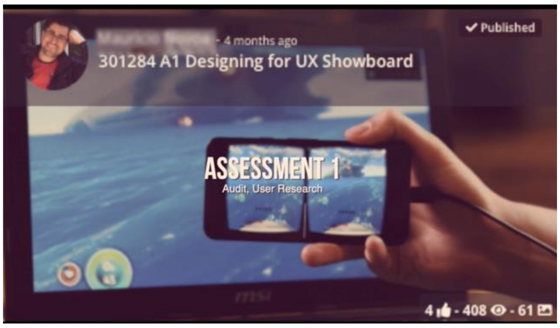

Figure 1. A1 VR Controllers testing

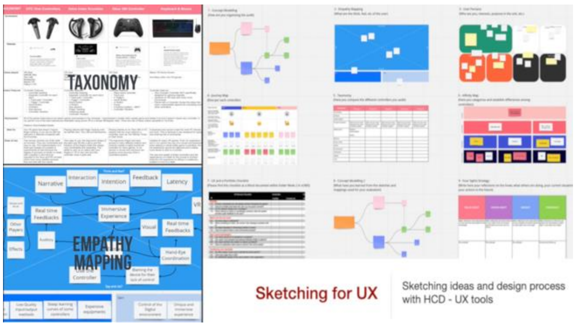

Figure 2. A1 MKM ePortfolio and UX

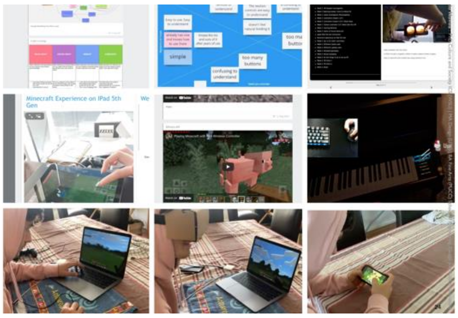

Figure 3. A2 VR Design and user evaluation

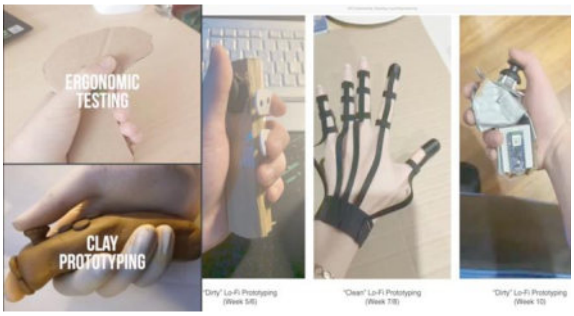

Figure 4. A2 Low-Fi and rough prototypes

Figure 5. A3 Working prototype testing

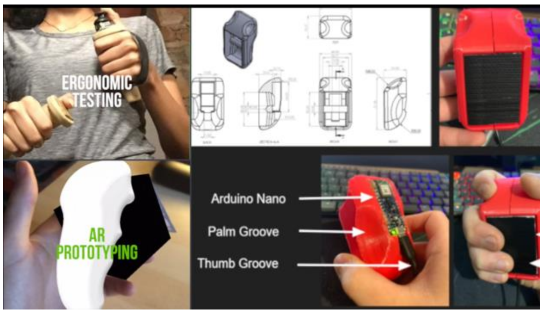

Figure 6. A3 AR test and physical prototype build

Figure 7. A3 final MVP prototypes

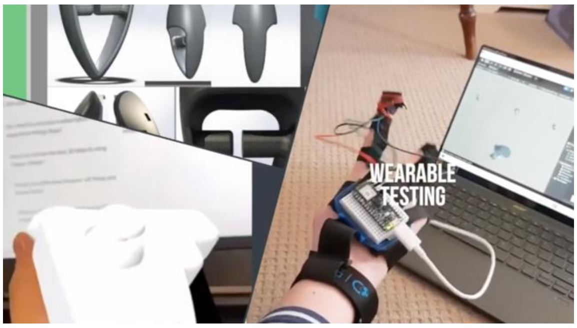

Figure 8. A3 final MVP prototypes

5 RESULTS AND DISCUSSION

Many challenges were conquered by the students in the coordination of the subject. From the start, students had to deal with general animosity created by pervading pandemic reasons larger than what they could manage. Further, they dedicated a great deal of their personal home space, which by today's standards is small, to work with new tools and materials that they did not know before. However, they were able to overcome adversity and their typical generational shyness and issues with concentration span. MKM ePortfolio work showed that they took to tinkering with simple materials (e.g., clay, origami, cardboard modelling) and using digital media with gusto to photograph, video record, take selfies, edit, and critique them in their process of analysis, design research and making. The heuristics approach of the subject helped them to increase their depth of learning and involvement as owners of an evolutionary process of experimentation and testing with no fear of failure. Gaming facilitated learning through play to code and trial their Arduino and Unit3D apps up to final MVPs and PVP working prototypes with verified evidence.

Certainly, independent university surveys on students' feedback on the subject and teaching showed their support. Broad agreement with the subject was at 100% and above our school and the university which was 92%. While explicit overall satisfaction was 86% and still above our school at 82% and the university at 80%, in detail inspection showed that students clearly supported 100% of the learning activities, and learning materials provided but the overall statistics were brought down by matters such as the lack of opportunities to work with other students (57%) and the available technology (86%) that were either unmanageable because of Covid-19 lockdowns or affected by students' own bandwidth access to the Internet. Positively, feedback on teaching was both broadly and explicitly 100% while school and university broad agreements were 93% and 94% and explicit agreement was 86% for the school and 87% for the university. Qualitative comments on Need for Improvement column ranged from answering "*None*" to the Best Aspects column with comments as being "*able to learn how to code and create a VR controller from scratch," "playing around with new technology"* and *"The hands-on parts of the subject, and the subject matter itself in tutorials".* Highlights on feedback on teaching showed that students appreciated the teachers were *"very approachable and willing to help with whatever issue I have"* and that students had access to *"previous work and putting up videos with examples to understand criteria and assessment tasks."*

Students' own survey feedback showed the same type of discussions held openly in class. A minority said to prefer that the lecturer provided checkbox lists and templates to copy and paste into their work. The larger group embraced an attitude against a *"high-school mentality" "where instructions and information are handed to you, rather than independent learning"* and *"adult learning."* Significantly among others, one feedback encapsulated the subject makeover to critical pedagogy, critical design, and critical making with playful learning best *"I really liked this unit and its assessments, designing a VR controller was such a cool and fun idea. I liked that each of the assessments followed the previous one, it was good practice in following the typical design process. I also appreciated the flexibility of the subject's marking criteria/outcomes, as in, there was no specific design, design process, prototype, fabrication method that had to be used/followed/produced in order to meet the desired ends. I believe that the way in which it was marked was a lot more realistic to working in the industry."*

Evaluation of the 2021 experience among the teaching staff helped to fine-tune the subject for 2022 with similar results. However, students enjoyed live classes and access to workshops, the in-campus attendance did not prove to influence remarkably better outcomes. Students said to relish socializing among themselves but that was simply an add-on to their ongoing digital media conversations through direct messaging, Facebook, WhatsApp, etc. Besides that, they said that felt that they had gone back to business as usual. On the side of critical pedagogy and its corresponding critical design and making, students commented that tried to apply them now working face-to-face but, unfortunately, they seemed to be occupied with domestic matters that they did not have before, such as leaving earlier to attend other classes in different floors or buildings, going to check models downstairs in the workshop, or running back to the public carpark to drive home quickly and avoid parking fees. It was different to before when they concentrated on conversations and discussions in the live Zoom sessions. They also said that they missed our Zoom challenges when we played for who would win for the best photo or video background, and the funniest avatar or outfit.

6 CONCLUSION AND RECOMMENDATIONS

This paper showed an example that a subject can be converted from transactional to transformational pedagogy in one term and that students, nevertheless fresh in the first year of their course were able to adapt and run within student-centred and critical learning methodologies. Also, that excellence does not depend on the acquisition of expensive and sophisticated technology. Instead, often low-level and simple technologies that align with people's interests seem to be adopted and stay longer with end-users, like in the case of Zoom and playful learning. Our students excelled and raised above expectations in difficult times. However, it is still to be seen whether lessons from lockdown times can expand to all our industrial design subjects and courses. As per students' comments, they seem to be experiencing back-to-serious business as usual. Admittedly, we are not out of the Covid-19 pandemic yet and they are also feeling the pressure of raising costs of accommodation and living while there is no improvement in salaries. As for the subject of *Designing for User Experience* and its focus on VR, new areas of development emerged that should fit the interest of a new kind of industrial designer and colleagues in design and engineering education. From working with open-source platforms to transforming education into playful immersive learning and to redefining the design process with new singularity workflows that collapses and simultaneously move between ideation, design, development, production, and delivery of design artefacts and systems made from both physical and digital materiality.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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MATCHSTICK MEN - TEACHING 1ST YEAR DESIGN STUDENTS' EMPATHY THROUGH DESIGN FOR PRISON LIFE

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ABSTRACT
How can we teach empathy to design students? How might we encourage them to consider people beyond their own perspectives? Can Product Design students be empowered to make a positive change in the life of another? Here we propose a way to start the conversation, using matchsticks. This project challenges universities to beyond the obvious ethical and social issues framed around sustainability and asks Undergraduate Design Students to engage with a demographic that is typically underrepresented both in society and in design intervention, Prison Offenders. In order to encourage a more empathic approach to Design, working in collaboration with a UK Prison, First Year Product Design Students at Nottingham Trent University were set a Design Project that challenged them to improve life within the confines of a prison cell. Over the course of 2 weeks, student groups were tasked with creating products that improved quality of life within a prison cell, utilising matchsticks, and construction techniques available to inmates. Guided by an expert Custodial Educator, students collaborated to generate visual, wordless guides that would enable any inmate to generate their products.
Overall, the project was a success, with a number of innovative outcomes being produced, and empathetic skills being developed, however, there are areas for improvement which we discuss. The results were confirmed via an anonymous end-of-project questionnaire with students commenting that the experience was immersive and designing from the perspective of a Prison Offender being a truly unique opportunity.

Keywords: Human centred design, design for under-represented perspectives, empathy, product design education

1 INTRODUCTION
Empathy within design is a fundamental component of Human Centred Design and Design Thinking, considered by many to be the fundamental bedrock of Modern Design Education [1][2][3]. Often, we ask our students to empathise with the user, to 'put on their shoes' in order to see how their lives could be improved through design. Various tools for this exist already such as Interviews, User Journey Mapping and 5 Whys [4] and these allow students to begin the path to true empathy, but what about when we start to ask students difficult social questions or challenge them with users beyond their easily accessible parents or roommates? Is it possible to empathise with a user so different from yourself? Someone whose wants and needs perhaps fundamentally contradict your own. What about Prison Offenders?

'Producing thoughtful, talented graduates is not a matter of focusing on market-ready skills. It's about giving students an opportunity that most of them will never have again in their lives: the chance for serious exploration of complicated intellectual problems, the gift of time in an institution where curiosity and discovery are the source of meaning.'[5]

This project set out to explore the depths of empathy and push Undergraduate students to think about bigger societal issues. It challenged them to think about Sustainability beyond recycling and upcycling, into empathy for nature and others. To build a social consciousness that goes beyond sympathy and

compassion.[6] In addition to encouraging empathy and a human-centred design approach, this project allowed students to reflect on the designer's role, giving space to contemplate their own purpose and role within the design industry. Typically, university projects are driven towards work like experience and portfolio building, meaning projects are often commercially motivated. This project allowed students the opportunity to work outside of their commercially driven comfort zone and presents them with a real-world opportunity to make a positive impact on the lives of others.
It was useful to consider the ethical impact of Design for Offenders, and the effect this may have on them and our students. The Prison engaged with in this research is a Maximum-Security Centre, with inmates having a minimum of 10-year-long sentences. As such, and due to the project being run over a small time period, direct contact between students and inmates was not possible.

2 APPROACHES

The project was undertaken due to a perceived lack of empathy from the students studying in the first year. From previous work on Personas and Design Thinking workshops, it was clear that students were struggling to empathise with those beyond their typical frames of reference. It was felt that in order to make students better Designers, and people, a project working with unexpected clients would help to push them beyond their comfortable routines. There is also a tendency within UK HE Design Education to focus on London-centric Design, producing conceptual visuals for the affluent, and tending to the needs of blue-chip clients. This project aimed to demonstrate to students there are other people to design for, and that Design can be a force for meaningful change within society. Through discussion with a Custodial Educator (CE) working within a local Prison, a project to highlight these opportunities and inequalities was formulated, that would challenge the students to think beyond themselves.
Collaborating with the CE, we looked to simulate the environment of the Prison within the University Studio. A mock-up cell was constructed within the Studio space, to allow the students to empathise with the environment they were set to create for. The intention was to create a sense of immersion within the prison world, to help students better understand the constraints placed on creativity, and to build on the concept of ‘learning through doing’ [7].

Figure 1. Mock Cell Set Up & Demonstration

This immersion was further developed by limiting the creation tools to those available within the prison. The students were limited to designing and creating only with Matchsticks, as this is a popular pastime within Prison and a widely accessible resource to Offenders. No scissors, knives, or hot glue were made available, and any tools required had to be created by the students.
The prison cells were marked out and left up in the studio for the remainder of the project for students to refer back to. In addition to an alteration of the physical environment, students were communicated with as though they were Offenders and had access to personal belongings (including phones) limited throughout the day.
The students first undertook a Workshop with the CE, to understand the viewpoint of an Offender in a cell, and the resources available to them. This workshop focussed on basic Matchstick Art techniques,

as well as highlighting some of the unique tools and methods the Prisoners utilise in their process. Student groups then had 2 weeks to ideate around the Matchsticks to generate useful cell objects and produce instructions to disseminate the knowledge. The project culminated in testing these instructions on other groups, to see how successful the transfer of knowledge had been.
Whilst it is important to acknowledge the reasons behind Offenders' incarceration, it must be remembered that Prison's main purpose is rehabilitation. As such this project was built around the idea of potentially educating Offenders with new skills and opportunities, to improve their lives within the Prison whilst showing how practical skills can be applied in the world after Prison. This is similar to the work of the Koestler Arts trust who aim to '*reward achievement*, *build self-confidence and broaden horizons for some of society's most disadvantaged and marginalised people*.' [8] The workshop was built around existing Offender art conventions, and the tools/resources available to them. This provided useful constraints to the student ideation, whilst providing skills that were somewhat useful to Offenders, without providing an opportunity for misuse. For the Offender, the project would allow a new perspective of design, and therefore creativity as often these are not seen as useful skills, '…*design, as applied creativity, might prove attractive to those who feel that 'arts' practice is too far away from vocational values to merit investment.'* [9] Whilst the scope of this project did not extend into interaction with Offenders in this instance, it was important to also have this discussion with the students throughout the project, to ensure not only the learning and HCD approach were fully applied, but that their personal criticality was challenged.

3 DISCUSSIONS

3.1 Set Up and Project Introduction

The limitations placed on the projects were the key drivers to developing empathy in the students. This was demonstrated through observation of student conversations where they reminded each other of the limitations of tools/space throughout the project. For many student groups, this was the driving factor behind their work, with a clear emphasis on what could and could not be achieved within the typical prison cell.
Limiting access to personal belongings during the day heightened immersion in the experience by replicating a sense of isolation from the outside world. Upon being told they could not use personal belongings for the day by the CE, there was a clear sense of unease within the student cohort. This challenged them to think and work outside of their usual comfort zone and to consider how this challenge could impact daily life, particularly when being asked to complete a task.
Although the initial Cell room set-up gave valuable insight into resources and space available, its full effect was limited due to students not being able to fully understand the isolation of a prison environment. After completing the project, it was clear that access to personal belongings should have been limited across the whole project, rather than just for one day. Not only would this have served as a reminder of resource limitations, but removing personal belongings for the whole project may have encouraged students to think more creatively within the confines of the Cell.

3.2 Working with Limited Materials

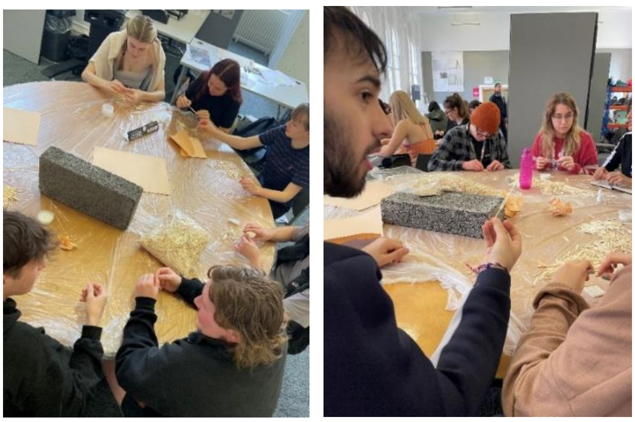

Figure 2. Students working with limited materials

To give students as close an experience as possible to prison life, only materials available within a prison cell were made available, meaning students predominantly only had access to PVA glue, matchsticks, and paper/card. Due to the limited time frame for the project and a lack of familiarity with the material, students were able to access an unlimited amount of these across the two weeks, in contrast to Offenders who have limited supply. Offenders often spend months working on their matchstick creations, generally with no time constraints, working slowly and methodically. In doing so, they become very familiar with the material and work thoughtfully to create intricate, personal objects. Our students were challenged with being introduced to the material and coming up with a tangible output within two weeks. This meant having to work quickly to understand the potential of the materials.

To alleviate the unfamiliarity with materials, students had unlimited access to them. However, providing this free access meant students weren't necessarily thinking carefully about how to use them, juxtaposing the realities of a prison environment. Students highlighted in particular that the PVA glue was difficult to use alongside the matchsticks. Ideally, students would have left more time for the matchsticks to dry before moving on to the next steps of their build, however, there was a clear awareness amongst the cohort that they needed to work relatively quickly and so these steps were often rushed.

In future iterations of this project, it is important to consider how we might facilitate a greater level of confidence in materials usage, potentially by giving students more time to become familiar with materials prior to the project itself. This would allow the project to align itself more accurately with the prison experience by limiting the number of materials used, without sacrificing student ability to experiment and familiarise themselves with materials.

3.3 Project Outputs

The brief tasked students to produce and deliver an innovative product made from matchsticks, presented as visual instructions, which had a positive impact on Offenders' lives within their cells. The instructions needed to demonstrate the key steps within the construction and allow another person beyond their team to construct the solution successfully.

Overall, all teams produced viable project outcomes, however, the realisation of the visual instructions was limited. All groups came up with a matchstick product that would be suitable for the prison cell environment, however, the final visual instructions generally lacked refinement and appropriate detailing. One key consideration for these instructions was that they should not rely heavily on written language, given that according to the Shannon Trust "over 50% of people in prison have a literacy rate below that of an 11-year-old".[10] Whilst most student teams had omitted any vocabulary from their instruction manuals, the visual communication of their ideas lacked thorough explanation. Predominantly, this can be put down to the time constraints of the project, and the difficulties caused by student group work dynamics. Whilst the time frame allowed student groups to empathise with the inmates in terms of making ability, material constraints and tool availability, the lack of literacy skills of Prison Inmates seemed to be overlooked. Had students been given more time to focus on this towards the end of the project there may have been more suitable instruction manual outcomes. For future projects, this should be taken into consideration and emphasised by staff as a clear priority for the final outcome.

Whilst instruction manual outcomes were not as successful as expected, the main aim of this project was to give students a chance to work with underrepresented groups and to consider the alternative user, outside of their typical university experience. Based on the success of the matchstick products themselves, it is clear that students were able to develop enough of an empathetic perspective to deliver appropriate physical outcomes.

3.4 Working in Groups

Whilst Inmates would typically work on these projects individually, the decision was made for students to complete projects in groups, predominantly due to time constraints and a lack of familiarity with materials.

Student feedback indicated that this could have been an individual project, with some commenting that they felt held back by group collaboration and progress. Given that Inmates usually produce matchstick models independently, this is not a surprising finding, however, the two-week time frame meant students would have experienced an even steeper learning curve had they been tasked to work individually.

Furthermore, the authors themselves noted that the matchstick modelling was fairly small-scale and complex for a group of 5/6 students to be working on at a time. However, working within a group setting allowed students to divide and delegate jobs between themselves, meaning that those with more CAD / Graphic Design interests could focus on the instruction manuals and those who were more interested in modelling could focus on the matchstick products themselves. Overall, the group-working nature of this task was imperative due to the limited time frame, however future iterations of the project could look at giving individual students a longer time, in order to achieve more personalised and empathic outcomes.

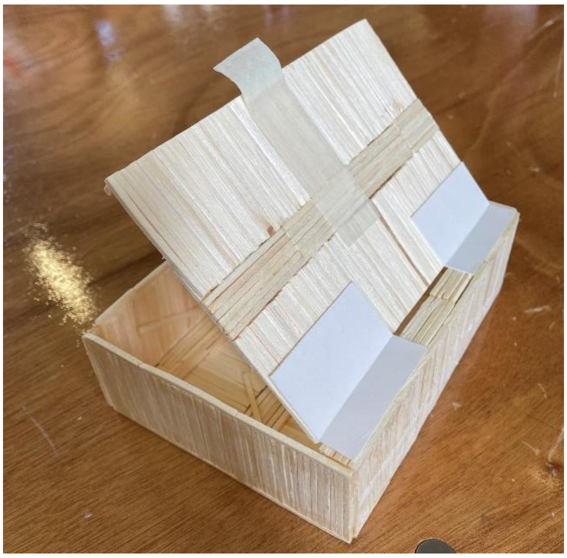

Figure 3. An example product created during the project

3.5 Time Frame

It would have been beneficial to give the students more time to reflect upon their experiences and receive feedback from their intended user. Final instructions were tested between groups in the class with some feedback from the CE, but a deeper learning experience could have been created if more time was given to iterate based on the feedback received. As such, the single test run highlighted gaps in the instructions that would need addressing before they could be real-world tested. To address some of the earlier issues, perhaps adding a test point after the first week would have helped to improve the quality of Instructions, and thus force the teams to work more effectively. But this would have led to a lack of development time with the Matchsticks themselves. This is a key area where the project could be improved and provide the possibility of real feedback from the Prisoners. A build/test/refine model could help to validate the instructions before they were tested out in the true environment.

3.6 Student Perception of Project

Very engaging and fun project, I loved the fact that we were working within a very different context. It was very immersive! (Student Participant 16)

Overall, the project can be viewed as a success, with students developing their knowledge of unusual materials, visual communication and their perceptions of who a user can be. A post-project anonymous questionnaire was employed to gather views and opinions on the project, with 27/28 respondents stating positive feelings towards the project (50% total response rate from the cohort). Students praised the input of an Expert in the CE to bring a level of realism and insider insight to the project, and they enjoyed the opportunity to design for someone very different.

It was really interesting trying to design for prison inmates given their truly different experience as a user (Student Participant 5)

The aim of the project was to develop the student's empathy skills, and the Authors believe this was successful within the constraints discussed above. The input from the CE was vital to the success of the project, and the Authors encourage an Institution looking to replicate a similar experience to ensure they contact a local expert. The CE input helped provide a level of realism to the experience that would be impossible to replicate with teaching staff. Their insight and tacit knowledge of the environment and users, combined with a hard-line approach to discipline and education, promoted an active learning environment, unlike a typical University Design Studio.

4 CONCLUSIONS

Overall, the project can be deemed a success, with opportunities for further development to be discussed and implemented in the future. The nature of empathy is not fully quantifiable so is difficult to measure completely, however the opportunity for students to develop their empathy was presented, and there is clear feedback that the project had a meaningful impact on the students. Consideration needs to be made to the use of materials and the outputs possible within tight timeframes, as well as the typical dynamics of student group work going forward. Generally, it can be considered that projects of this nature present novel opportunities to promote empathy, and we encourage other Academic establishments to build upon our work.

5 OPPORTUNITIES FOR FURTHER RESEARCH

This project and its topics present key areas of opportunity for the empathetic growth of students. Our project acts as a trial study for this and could be built upon for further impact. More integrated collaboration would be a key factor for developing the project, with the ultimate iteration being full interaction between Students and Offenders, within a Prison setting. Clearly, this poses safety, ethical and logistical issues, but presents opportunities for co-design and meaningful impact in severely marginalised people's lives. This could be scaled back to Offenders who have been rehabilitated visiting Universities, or deeper integration of a CE or other Prison Staff to the projects. A deeper level of immersion could also help to activate empathy, perhaps with the construction of Prison cells to ideate in or simulating, to a degree, some of the pressures created by incarceration. As mentioned, the key aspect for developing empathy within students is providing time and space for them to discuss and reflect on their work and personal points of view. Any project that helps to develop these skills will impact our students to make sustainable, ethical choices in their projects and their future Design careers.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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A TOOLBOX FOR ADDRESSING SHAME IN DESIGN PROJECTS

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ABSTRACT
In various master projects and workshops, we have experimented with a toolbox aimed at assisting designers with understanding self-conscious emotions such as shame, embarrassment, and guilt in relation to design challenges. The rationale for doing so is that using conventional methods of inquiry have severe limitations in understanding the role shame and related concepts have in supporting and hindering desirable sustainable, socially acceptable, and healthy s. This paper presents the toolbox which includes shame stretching exercises, inverse empathy mapping, a meme tool, a 'Shame Cues' card deck, and making fake news reports. We reflect on how students and workshop participants use these tools and how they contribute to their ability to better articulate shame related aspects, identify opportunities for design interventions based on removing or adding shame, and in general to raise norm critical awareness.

Keywords: Shame, self-conscious emotions, design tools, design methodology, norm-critical design

1 INTRODUCTION
Social phenomena which are taboo-prone and in which self-conscious emotions such as shame, guilt and embarrassment play a role, are of increasing interest for students [1]. Such topics not only share a high level of complexity which is strongly affected by norms, culture, and politics, but they also challenge students in their ability to deal with the more sensitive sides of society. Design education in general equips students with a toolbox that enable them to understand social phenomena, to raise good questions, map contexts by using interviews, surveys, focus groups, cultural probes, and use of other ethnographic methods. However, this toolbox becomes less straightforward to use when dealing with self-conscious emotions, addressing dark spots in society or having to ask awkward or embarrassing questions. In connection to an ongoing PhD project focusing on the role of shame in design [2], we have since 2021 successfully recruited master students who wrote their final master thesis on shame related topics. During this period, we have developed several tools dedicated to research these taboo-prone topics where shame, embarrassment, awkwardness, peer pressure, stigma, and other nuances of shame play an important role, and where traditional methods of inquiry would have shortcomings in uncovering such hidden and very personal user insights.
The aim of this paper is to present the toolbox in its current form, explain the tools' purpose and provide examples of their use in projects and workshops. Based on this we reflect over their potential contribution to enabling designers to identify, articulate and address elements of shame and related concepts in design project. The tools are:

- a 'shame-stretching' tool, allowing for exploring boundaries in what is, for example, mainstream, odd, subculture, and illegal behaviour (Section 2)
- inverse empathy mapping, focusing on what people do *not* say, hear, feel, think, and do (Section 3)
- a meme tool, exploring alternative expressions of feelings and opinions which are not necessarily easily put in words (Section 4)
- an inspiration card deck tool named 'Shame Cues' showing how shame and related feelings manifest themselves in social concepts (Section 5)
- developing fake news reports in relation to proposed design interventions (Section 6)

The use of the toolbox is illustrated by sharing examples of its use in practical projects, including the aforementioned master projects as well two full week workshops and a two-day workshop with professionals (Table 1). The paper concludes with reflections by both students and supervisors on using these tools and how they complement the standard designers' toolbox.

Table 1. Overview of project and workshops in which we experimented with the toolbox

Context	Themes	Tools used
7 master projects (30 ECTS)	Safe personal sexual exploration for young male adults; "Sending nudes" culture in secondary and high schools; Rethinking gender roles in design education; Design in the context of economic shame; Rethinking (voluntary) childlessness and the nuclear family; Design for male mental and physical health and wellbeing; Exploring design interventions to improve the role of next-of-kin to those who have eating disorders	Free for students to choose; on average two tools used per project.
5 Master level specialisation projects (15 ECTS)	Partly the same students, and therefore partly overlapping with the above themes. In addition: Reducing denial of own alcohol abuse.	Free for students to choose: on average two tools used per project.
2 full week workshops (3 ECTS)	During the Xplore Design Week 2022 and 2023 at the University of Antwerp: Two times four groups of 3-4 students, focus on themes including body-shaming, excessive alcohol consumption among students, awkward situations related to cutlery use, shame related to doing activities as a single person, awkwardness related to situations in dressing rooms and more.	During first 2022 workshop all four groups used all tools except Fake News Report During the 2023 workshop the focus was on Shame Cues and Shame stretching, as well as Fake News Report
1 two-day workshop with professionals	A two-day qualitative 'pee-poo-period' workshop with eight professionals from design, architecture, and art, focusing on disposable products connected to urination, excretion and menstruation.	Focus on shame cues, meme tool, shame stretching

It should be noted that the tools are still prototypes and have in varying degrees undergone iterations in between the various student projects and workshops they have been tested in.

2 SHAME STRETCHING

This exercise was originally devised as having two parts. One is a canvas on which to lay out different examples (from memory, on-line sources or pictures taken from real life) related to a social phenomenon or practice, to challenge students to find shame-prone aspects related to that practice. The canvas (Figure 1) fades out from a large white area which is placed in the center, to a black rim on the edge of the canvas. At the center, examples reflecting 'normality' are placed, i.e., those which can be connected to, say, 80% of the population. Away from the center, darkening grey tones reflect examples which become gradually more uncommon; these are 'good for some' but 'not as good for others' and can be connected to the more adventurous (estimated ca. 1 out of 10 people) or to subcultures (1 out of 100). The black rim would then carry manifestations which include fetishes (perhaps 1 out of 1000 or 10000), and at the very edge extreme moralism or hedonism, representing manifestations that are rare, possibly taboo and/or illegal. For every manifestation, students are to collect many manifestations related to a social phenomenon or practice, which are then to be discussed: are they public, hidden, is there shame involved, and if yes, are they hidden to protect oneself, or others? In the context of clothing for example, one would play aspects such as *covering normal body parts*, *wearing mass produced brands* and *gendered clothing* at the centre. *Shopaholics* and *second-hand clothing* would come next, followed by subcultural aspects such as *cross-dressing*, *naturism*, *wearing white tennis socks under casual clothing*, before arriving at the black rim where *religious clothing traditions* and *clothing fetishism* would be placed. The second part of the shame stretching exercise is to challenge student to find various cues or signs of shame (including those extraverbal) and place them on a canvas, stretching between extremes and exploring nuances of shame. These cues (or signs) of shame could be memes, Instagram posts, research articles, forum threads, Wikipedia articles, news headlines, advertisements, etc., that participants found important for their topic. Suggested examples of extremes are from affirmative to norm-critical, or from subtle to explicit. In the pee-poo-period workshop which is further reported on in Trondsen et al. [3], participants chose for example hidden-accessible, private-public, and clean-unclean to sort examples related to personal hygiene.

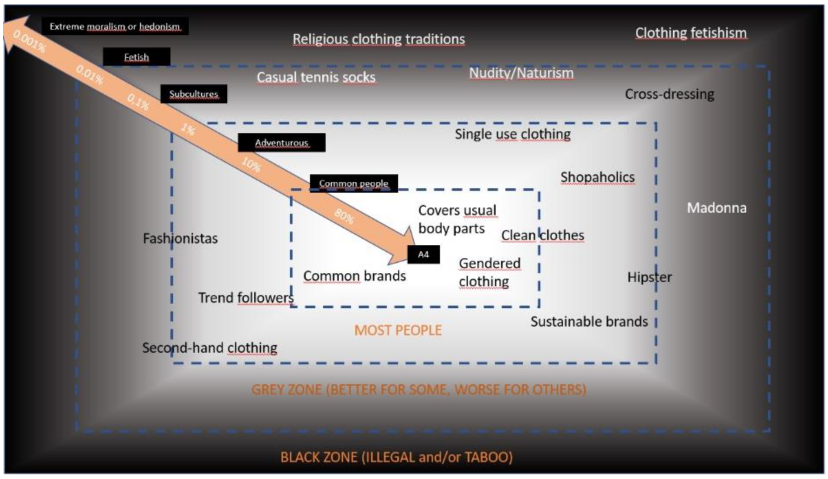

Figure 1. Shame stretching canvas

3 INVERSE EMPATHY MAPPING

Inverse empathy mapping is proposed as a variation on the well-known empathy mapping canvas, originally developed in 1993 by XPLANE founder David Gray as a collaborative tool for human-centred design which essentially challenges designers to uncover what people think, see, hear, say and feel. Instead, inverse empathy mapping is to challenge designers to uncover what people do not, or do not want to think, see, hear, say, and feel (Figure 2). The original empathy mapping tool was already noted by one of our students as one of the existing tools that was easiest for her to identify potentially shameful issues with because it addresses feelings and thoughts. In a workshop setting, she first used the original tool, and then used the inverse empathy map. This revealed that participants managed to identify potential shameful issues in the first round but were not able to articulate these clearly until they used the inversed version in the second round. But even then, they did not use the actual word 'shame' in their articulations before the student suggested it. Workshop participants also indicated that it was useful to use the original empathy map first, and that a two-step approach probably was better than only using the inverse empathy map, likely because it juxtaposes what people do and do not (want to).

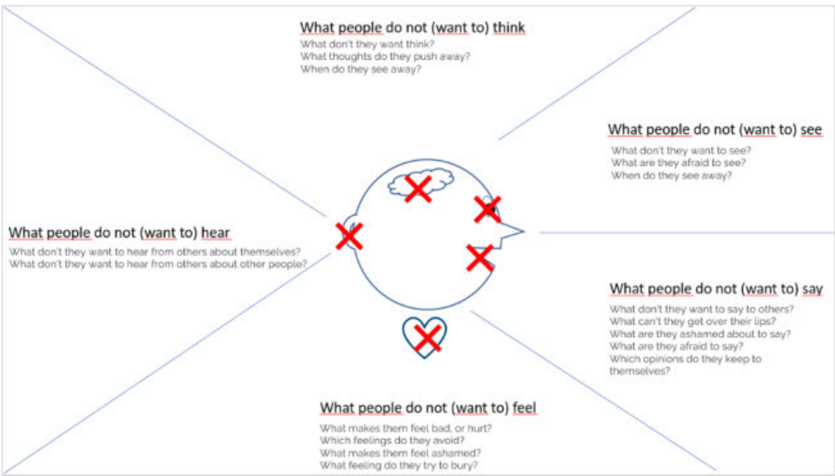

Figure 2. Inverse empathy mapping canvas

4 MEME TOOL

Internet memes are cultural expressions based on images which are augmented with text, where the image is chosen to convey a visual interpretation of the text's meaning. Memes are often taken from popular culture, and contain elements of humour, irony, and self-consciousness. Because meme images are often reused, they can grow to become popular conveyors of a certain core message, applied in similar contexts, and may gain viral dissemination. Zittrain [4] states that a meme at its best exposes a truth about something, and in its versatility allows that truth to be captured and applied in new situations. Especially for younger generations in this social media dominated era, internet memes can be considered as a popular mode of discourse, and a convenient way to anonymously articulate how feelings of shame, embarrassment and awkwardness play a role, and where conventional spoken or written language is insufficient to convey ideas, feelings and opinions. In the context of our design and shame projects, we have proposed our students to collect and study memes to capture the essence and nuance of certain complicated social phenomena. Mining user-generated content like memes appears ill-explored as a research method or design tool, although Engel et al. [5] already stated that they can be used by students to artfully show their comprehension of key concepts. Along that line of thought, we pose that memes, when mined from the internet and consequently studied, can provide a comprehension of a phenomenon which cannot be gained from studying the spoken and written word, and can therefore be seen as a means to gain insight as to what users think and feel, but will not communicate to researchers through conventional means of inquiry. We propose that students study memes by doing exactly what the meme intended to avoid: explicitly write out how the meme works and why. For example, suppose the 'Sceptical Third World Child' meme in Figure 3 would have been collected in the context of a food waste project. Students would then be expected to explain how it is used as a crude stereotype of Africa as war-torn, poor, and suffering constant food shortages, how it is used to juxtapose and ridicule supposedly irrational Western behaviours, and how it provides a mirror for western consumers with respect to their food waste behaviour, evoking shame about the fact that they try to solve a waste problem which shouldn't be there in the first place.

Two of our students wrote their master thesis about 'shame and men's health from a design perspective and used memes extensively to capture different aspects of the relationship of men with health. After gathering dozens of memes by searching the internet, they sorted them in eight categories, including 'Feelings of loneliness and lack of support', 'Helplessness and *man up'*, 'Negative experiences related to opening up and showing vulnerability', 'Criticism on how society looks upon men's health' and 'Doubts related to going to the doctor or not'. One of the key insights in their mapping process was that there is a clear need to express feelings about shameful and awkward aspects related to men's health, and that many do this through memes, and that community feeling and expression through memes may create social awareness and acceptance. The students combined the collection of memes with shame stretching by sorting the memes along two axes (from memes which ridicule men and call out for shaming them, to memes which call out for sympathy and removal of shame) and found that memes could be placed at both ends of the axis.

Figure 3. Meme example

5 SHAME CUES

Shame Cues is a card deck designed to help designers understand, reflect upon, and play with social concepts where shame (and related concepts such as guilt, embarrassment, and awkwardness) plays a central role. It consists of 64 cards divided in 16 categories of social concepts which can be related to how shame manifests itself in society (Table 2). Much of how the concept is captured, verbalized, illustrated, and described on the cards stems from public discourse, and has been extracted from various non-academic and informal platforms such as Urban Dictionary, Wikipedia, Pinterest, memes, Imgur, Bored Panda, Reddit, Quora threads and so on. The Shame Cues tool has been used in different ways in the various projects and workshops. In its latest iteration, users of the tool are tasked with collecting examples of how a certain phenomenon (for example dumpster diving) can be connected to the cards and how; for example, *pussyfooting* may be connected as having a negative effect on dumpster diving, because people who may want to join a dumpster diving community may hesitate, thinking that they won't be accepted or considered external to this social group. Similarly, vicarious embarrassment may be relevant, considering that others may be embarrassed on your behalf and may therefore hinder people from dumpster diving. On the other hand, *snooping*, *morbid curiosity*, or *guilty pleasure* may have a positive effect as it can be tempting or satisfy curiosity to investigate others' (food) trash and bring associations with treasure hunting and getting something for free. A second part of the exercise is to pick random cards which in the first round had not been selected and see if examples can be found to illustrate the potential relevance of the card, to uncover blind spots and further increase the designer's understanding of how aspects of shame (added or removed) may play a role in contributing to the desired behaviour.

Table 2. Overview of categories and shame cues in the card deck

Exaggeration Sarcasm Camp Shamelessness Satire	**Counter action** Counterculture Reappropriation Subculture Civil disobedience	**Humour** Dad jokes Dark humour Schadenfreude Irony	**Vulgarity** Taboos Profanity Karen stereotype Vulgarism
Dark attraction Morbid curiosity Forbidden fruit Innuendo Neophilia	**Pleasure** Benign masochism Naughtiness Guilty pleasure Eccentricity	**Secrecy** Closeting Snooping Eavesdropping Sweeping under the rug	**Softening** Euphemism Metaphors Stylizing Awkward turtle
Covering Pardon my French Gedoogbeleid Sanitizing Sugar coating	**Awkwardness** Oversharing Personal space invasion Verbosity Awkwardness	**Embarrassment** Pussyfooting Cringe Vicarious embarrassment Overpraising	**Slang** Cheesiness Tackiness Corniness Geekiness
Guilt Confession Guilt tripping Guilt hibernation Sympathy card	**Moralising** Sanctimommy Political correctness Holier-than-thou Outrage culture	**Humiliation** Public humiliation Walk of shame Badge of shame Mockery	**Separation** Scapegoating Stigmatizing Cancel culture Shunning

6 FAKE NEWS REPORTS

In master projects we expect students to articulate the ideas behind the interventions they develop, by explaining how and why adding/removing shame will address challenges in a health, social or sustainability context. However, in workshops there is little time for explicitly documenting the ideas behind such interventions. Inspired by Hebrok & Mainsah [6] who used purposely designed fake news in their design fiction project BIRD, we found that asking students to articulate such ideas using fake news reports serves this goal of clarifying intentions behind their interventions surprisingly well. For students this proved to be an inspiring and fast way to articulate their ideas behind the concept, and during the final exhibition, many visitors reacted positively, stating that the fake news reports made it easy to understand the speculative and norm-critical designs displayed. A good example is the case of 'Crazy Cutlery', a restaurant concept which criticizes how society judge's people's eating habits, by offering random 'tools' like a small rake, a cheese grater, or a mussel shell, making it possible to eat inappropriately, and therefore a fun experience. Interestingly, in another project from the same workshop we found that the chatbot ChatGPT was surprisingly well able to convey the main idea of the intended design intervention, once fed with a number of key phrases.

7 CONCLUSIONS AND FUTURE WORK

In this paper we briefly introduced a toolbox for assisting designers and design students to understand how shame and related concepts can play a role in many situations and potentially hinder or support desirable sustainable, healthy or social behaviours. The tools do not require direct user involvement, and instead rely heavily on how social phenomena are depicted in culture and everyday life. We recognize that so far, our experimentation with the tools has not been systematic, and no final conclusions can be drawn, but aimed to share our initial experiences in the limited space available. First, we have experienced that by using these tools, students become able to internalize an understanding of shame, and to elucidate the concept in relation to the behaviour they are studying, and to use it for inspiration. It challenges them to think out of the box, especially in terms of opportunities for norm-critical and discursive design interventions which otherwise remain in their blind zone. Additionally, students think the tools are fun to work with; in particular the relation to the online culture they are well familiar with seems to inspire them. They also state that they become more aware of how shame plays a role in many design challenges and that they are much better able to articulate this after using the tools. It is our experience however that bachelor students find it challenging to use the tools in a free form way and experience them as confusing even when clearly told how to use them step-by-step. For example, letting students determine themselves which axes may be relevant for shame stretching proves challenging. Using the shame cues proved to be very inspiring, but many students seem to dismiss cards as not immediately relevant, whilst as supervisors, being familiar with its intended use and having experience with making quick associations, we had no trouble making what seemed obvious links to us.

The meme tool may probably not function best as a separate tool but can be easily integrated in some of the other tools, not in the least because students love to work with memes. Using some of the tools (notably shame stretching and the Shame Cue cards) with professionals (in the pee-poo-period workshop [3]), we found that they sparked discussion concerning the meanings and definitions of shame, changing social norms surrounding shame, and the influence of these norms on individual feelings and behaviours. The tools helped the participants spin off each other's associations, and ideas, contributing to collective thinking. The participants' experimentation with different polarities on the shame-stretching canvas illustrates how these tools engaged them to open their minds and include new perspectives. Clearly, the more experienced and reflected designers become, the easier it is to reflect on the impact of social norms, both critically and analytically. Our overall insights suggest that a better vocabulary and awareness of shame can support designers in identifying how this emotion can hinder and promote sustainable practices, and how they can more effectively design with shame in mind, resulting in ideas that attempt to challenge and counteract societal norms and taboos. In our future work, we will further iterate on the tools, keeping the above considerations in mind, and in particular focus on helping users of the tools to interpret the results more effectively, by diversifying the toolkit based on the experience level of the intended audience. On a final note, we acknowledge that the use of such tools may risk uncovering hidden issues for students that may require emotional support. We have extensively addressed this issue in a previous E&PDE paper and will continue doing so.

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LONGITUDINAL EVALUATION OF SELF-ASSESSMENT AND PEER REVIEW IN A CAPSTONE COURSE

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ABSTRACT
One crucial part of education is teaching students to critically evaluate and reflect on their work. One way to perform this is through peer review and self-assessment. In this research paper, we present the results of a longitudinal study over five years with 239 students following the implementation and evaluation of peer review and self-assessment. Using qualitative and quantitative analysis, we explore different types of self-assessment, the benefits of incorporating self-assessment into the learning process, and lessons learnt during the years. Results show that students appreciate assessing their own and others' work. The students in the study are very good at evaluating their capabilities, the difference between the self-assessment and teachers' final assessment was about 10%. With a studio-based approach, with formative feedback throughout the process, individual oral and written presentations and support from self-assessment, team feedback and teacher discussions, there is a much higher certainty that students are assessed accurately.

Keywords: Assessment, teamwork, peer learning

1 INTRODUCTION
One crucial part of education is teaching students to critically evaluate and reflect on their work. One way to perform this is through peer review and self-assessment. By peer review, students spend time reading and assessing other people's work, learning to determine what is good and bad [2]. Peer review can also be combined with self-assessment, a critical process that allows students to reflect on their learning and personal growth. It helps them identify their strengths, weaknesses, and areas for improvement, which is essential for personal growth and professional development. Peer review and self-assessment are valuable tools for self-regulated learning because it helps the students to set goals, monitor progress, identify and address areas of difficulty, and adjust strategies as needed. In this research paper, we present the results of a longitudinal study over five years with 239 students following the implementation and evaluation of peer review and self-assessment. Using qualitative and quantitative analysis, we explore different types of self-assessment, the benefits of incorporating self-assessment into the learning process, and lessons learnt during the years.

2 BACKGROUND
A common problem when assessing design teams is that teamwork can introduce free riding, where students rely on their teammates to carry the workload. Also, students in a group may have varying skills or abilities, and those who are struggling may hold the group back, while more advanced students may become frustrated with the pace or level of work. This can be a frustrating experience for other group members and lead to decreased overall performance. For the teacher, it can be hard to assess individual contributions accurately. Students working in a group often tend to specialise in specific areas based on their existing skills and interests. For example, strong vocal students are responsible for presentations, strong writers are responsible for documentation and students that excel in sketching and rendering is responsible for illustrations. As a result, some students may conform to their comfortable roles rather than challenge themselves and develop new skills. So, in the assessment, it is vital that all learning objectives of a course are assessed on the individual level. To evaluate the goals, some kind of

framework is needed. In 2015, the competence profiles [3] for Industrial Design Engineering were developed based on supporting students' understanding of the essential characteristics of an industrial design engineer. The goal was that the framework should help teachers and students understand how and with what quality a specific competence should be developed. The framework consists of eight different categories. Each category is further divided into sub-categories, visualised as a progression chart where the student starts as a beginner and can develop into an expert (an example of progression in communication is available in Table 1).

2.1 Peer review

Peer review between students has several benefits because it gives students constructive feedback from their peers, which can help them improve their writing and critical thinking skills. This feedback is often more relatable and understandable than feedback from teachers or professors. Something that is often missing is that students need to learn how to evaluate others' work and give good feedback. One way of doing this is facilitated peer-review sessions [1], where several students read a text, provide individual feedback and then have to discuss their feedback with others. This encourages collaboration, highlights different views, and creates a shared understanding of good and bad. It is also shown that the actual feedback is not the most crucial part. However, by reading and evaluating others' documentation, students also learn how to improve their own written text [1]. Peer review also empowers students to take ownership of their learning and encourages them to be active participants in the learning process and to take responsibility for their own progress.

2.2 Self-assessment

Self-assessment can take many forms and occurs when students make *"judgements about their own learning, particularly about their achievements and the outcomes of their learning"* [4, p. 529]. Panadero et al. [5] found 20 different categories of self-assessment. The typical self-assessment procedure includes self-reflection, self-evaluation, and self-grading to a more complex form of self-assessment that involve rigorous analysis of strengths and weaknesses in relation to explicit criteria. Self-assessments are a valuable tool for students as it helps them take ownership of their learning and empowers them to make meaningful changes to improve their understanding of design and assess the quality of their own work.

Boud [6] highlights that self-assessment contains two parts, where the first part is often neglected:

- The involvement of students in identifying standards and/or criteria to apply to their work.
- Making judgements about the extent to which they have met these criteria and standards.

To fully embrace the idea of self-assessment, it is vital to teach students the characteristics of good work, or as Boud states: *"It requires them to consider what are the characteristics of, say, a good essay or practical work and to apply this to their own work"* [6, p. 12]. Some general conclusions from the meta-analysis of self-assessment performed by Boud and Falchikov [4] and Pandero et al. [7] show that self-assessment more often agree than disagree with staff marks and that 'good' students tended to underrate themselves compared to staff marks, whereas 'weak' students tended to overrate themselves.

3 METHOD

Boud and Falchikov [4] recommended thirteen requirements for research studies on self-assessment that have been used as a guideline when reporting the study. They also identified a lack of replication with different groups taking the same course in the following years. This study is a longitudinal study of using self-assessment following five cohorts of students (2018-2022 n=239) using the same self-assessment criteria. All student quotes have been translated from Swedish by the authors.

4 IMPLEMENTATION

The implementation of peer review and self-assessment has been done in a third-year capstone design course. The role of the course in the program is to integrate knowledge and skills acquired previously in the program and focus on improving teamwork and interpersonal skills in a product design project. Initial reflections on the development of the course with a focus on academic writing have previously been presented in [1]. In the course, students work in small teams (3-4 students) that go through a design process with four phases. Students know when and what they should deliver at each stage gate, and then it's up to them to decide which methods are suitable for performing the design. After each phase, students present their progress and receive critique during four design reviews. They also produce a 4-

page written Process Memo (PM). The course ends with a presentation and documentation of the final concept. For each phase, a facilitated peer review and formative feedback from the teaching team (oral presentation and written PM) are used to improve the design, presentations, and documentation. In 2015 a facilitated peer-review process was introduced work [1] where students review others' documentation (PM1-3) and give feedback on a draft document, which is then updated before the teaching teams give feedback. Peer review saves time for the coaches, in a typical course, peers do more than 150 reviews before the teachers see the document. Formative feedback is essential because this is where students set the baseline of what is acceptable and what makes documentation excellent. Previous work [1] highlighted that most students appreciate the peer review sessions and believe it has improved the quality of the written documentation. The course evaluation also highlights that students think that the feedback from others is not the essential part; by reading others' documentation, they gain a better understanding of how good documentation is written.

4.1 Individual self-assessment

At the end of the course, students perform a self-assessment on *Communication* (oral, written, and visual), *collaboration* (active contribution to a project team), *create and develop* (Think and act innovatively and Prototype and test) and *Problem solving* (analysis). Students are informed of this self-assessment at the start of the course, previous research [8] [9] has identified the importance of presenting and discussing the assessment criteria with the students before starting the activity to ensure what will be assessed at the end of the course.

Table 1. Example of self-assessment of communication abilities

ORAL COMMUNICATION				
☐ NOVICE	☐ ADVANCED BEGINNER	☐ COMPETENT	☐ SKILLED	☐ EXPERT
Orally present work in a structured way, keeping track of time, and using appropriate aids.	Present ideas and arguments in a confident and persuasive manner	Use a wide range of presentation techniques for different audiences and situations	Quickly and convincingly answer questions and discussions based on discussions with various people	Present in English in a credible manner.

Self-assessment process:

1. *Self-assessment,* where assesses their own competencies and abilities and must describe how they meet the learning objectives (with examples from the course).
2. *Team feedback,* students' self-assessments are then reviewed by their team members, who give feedback on the student's assessments.
3. *Final assessment*, teachers review the assessment and do a final assessment based on students' assessment, team feedback and the interaction they had during the course.
4. *Quality assessment of feedback*, the teacher also assesses the quality of the feedback given to their team members.
5. *Teacher assessment* of the final documentation.
6. *Teacher conference*, teachers present their preliminary assessment of students, comparisons between teams' performance, discussion of outliers, feedback before the final assessment.

4.2 Team assessment of project work and documentation

In 2018 a self-assessment of the final documentation was introduced. In this assessment, the team had to argue why they fulfil the criteria for the documentation (developed by the examiner in the course). The same standards were then used by the final assessment by the teaching team, for details, see [1]. In 2023 we involved students in identifying standards and/or criteria to apply to their work in a documentation workshop three weeks before the deadline for the documentation. Student teams in the workshop had the opportunity to discuss what is essential for product documentation and develop their own criteria. The criteria were written on Post-its and pasted on a whiteboard. After the workshops, each student team had to write a rubric for three criteria.

5 RESULTS

The results are divided into quantitative and qualitative sections based on 239 students from 2018-2022. Six students were removed from the analysis due to missing self-assessment and/or peer review data.

5.1 Quantitative results

Table 2. Overview of self-assessment

	Number of students		Number of teams	Self-assessment		Teacher-Self		StdDev Teacher-Self	
Year	F	M	Total	F	M	F	M	F	M
2018	22	33	14	20,3	20,0	0,6	0,6	2,7	1,9
2019	16	40	14	21,4	21,7	0,6	0,2	1,9	2,4
2020	16	26	11	19,1	20,2	1,2	0,4	3,2	3,4
2021	23	23	12	21,7	21,1	1,3	0,6	2,8	3,3
2022	10	24	9	21,0	21,1	1,5	-0,1	2,3	2,3
Total	87	146	60	20,7	20,8	1,0	0,3	2,7	2,7
		233			20,8		0,6		2,7

From the results of the whole population, we can conclude that students are generally good at assessing their own work. The average difference between teacher assessment and self-assessment is less than 1 point ± 2,7 (Table 2), in agreement with earlier research [4] [10]. If we look at the difference between female and male students, it seems like females underestimate their self-assessment, i.e., the teachers will, in more cases, grade them higher than their self-assessment (Figure 1).

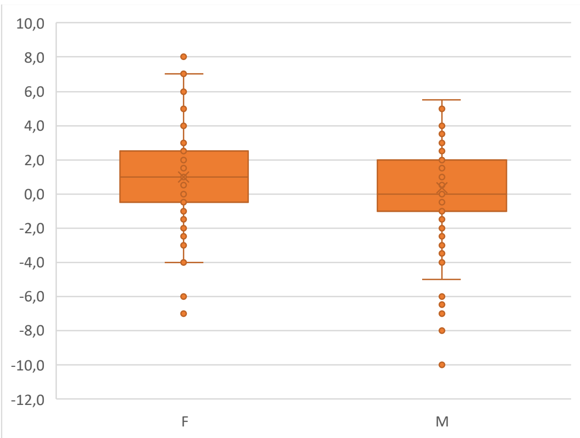

Figure 1. The difference between female and male students

Weak students often overestimate their work, and strong students underestimate their work. Many students with the lowest teacher scores assessed themselves at a much higher performance.

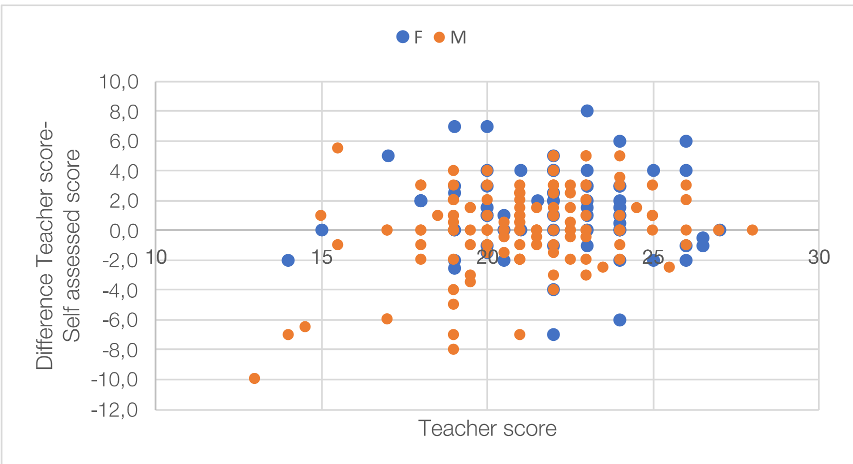

Figure 2. Plot over the teachers' final assessment (x-axis) and the difference between teacher-student assessment

5.2 Qualitative results

Qualitative results were mainly from the student feedback during self-assessment and course evaluations. The feedback on the self-assessments has been crucial in different ways. Team members often reinforce an assessment, and it is also quite common for team members to highlight personal competencies that students themselves may not be aware of. Finally, it also performs a 'sanity -filter', so students cannot take credit for something they did not commit.

5.2.1 Reinforcement and boost of students' assessment

Team feedback complements and reinforces students' own assessment: *"I was responsible for the presentation in DR2, I didn't use cheat sheets, and I got good critique from the teachers' you have good fluency and contact with the audience' in the presentation I used both illustrations and animations in the presentation. I also brought simple prototypes that I used during the presentation. In the final presentation, I was given the responsibility to present the needs of the users, in my opinion, I also did this professionally, here, I worked on getting a good flow in the presentation, moved and used more body language.".* Student argumentation on oral presentation (2018). Feedback from a team member*" You have chosen to value yourself as competent and I think that is correct, you also made an excellent presentation in DR2 and the final presentation. You have also participated and answered questions in a good way during all design reviews.".* Several students are restrictive and modest over their achievements and make a rather careful self-evaluation; commonly, their teammates raise their self-evaluation. "*You have selected 'advanced beginner' in your rating. I think you were a little too self-critical. You were the only one of us in the group who had tools to make and who made physical prototypes and made really nice ones with the user in focus!"* Feedback Prototyping F to M (2021). Another example *"I think you underestimate yourself in this part. In addition to all the criteria under skilled, you also looked at the members' competence and led the project forward. Definitely reached the level of skilled!"* Feedback contribution to a project team (2019). It was also common from the team feedback with suggestions on how to improve in the future: *"An area of improvement would be to spend a little more time on the initial sketches, as they have great importance for the project going forward. Overall, a great job!"* Feedback visual communication (2021).

5.2.2 Sanity filter

The team feedback works as a sanity filter, so students can't write about things they have not performed. Student A writes about prototyping (2021): *"Time constraints and certain difficulties in terms of construction limited the number of physical prototypes, but I was involved in creating and analysing the prototypes we produced in CAD.".* This was met by team member B "*Student A has been sketching during DR2. He also did the product calculation and some diagrams in DR1. He also made the animation shown at the final presentation. Renderings... yes, possibly 'to some extent'. Haven't seen any rendering.".* Another student in the same team responded, "*Student A has not shown any higher degree of prototyping or testing in this project. He was not involved in role analysis or testing of concepts in the workshop. His contribution to the CAD model probably accounts for 1% of the total time spent on the modelling.".* The overestimation of performance in the lowest-performing students is also visible in Figure 2.

5.2.3 Feedback from course evaluations

It was apparent that most students liked to evaluate their own performance. Comments from students in course evaluations highlight the benefits of having to assess one's own as well as others' performance in order to reflect on each team member's contribution to project work. Another often-mentioned benefit was the value of the self and peer assessments as support in self-development. The task of assessment was perceived as very difficult but fun.

5.3 Creating own criteria

From the workshop, student teams highlighted the following criteria as the most important for the final documentation *Product design 38%* (describing and visualisation of the product and its features), *Desirability 23%* (focusing on user needs) and *Feasibility 19%* (focusing on how the product fulfils critical functions and needs).

5.4 Teachers' assessment of individual work

When evaluating individual students, it is crucial that the teacher meet and interact with the students throughout the course. The course uses a studio-based teaching method, where each teacher follows a small group of students. Through the recurring coach meetings and design reviews, the teaching team monitors students and sees how they act during coach meetings, who understand product and process aspects, and who interact and answer questions during a design review. The four joint design reviews also allow the teaching team to evaluate team performance and compare teams. Even though most of the student's self-assessments are very close to the teachers' assessments, some students considerably overestimate or underestimate themselves (see outliers in Figure 1). This is discovered through team feedback and frequent meetings between coaches and teams, as well as all students being responsible for an oral presentation and a written document each.

6 CONCLUSIONS

This research presents the findings from a five-year longitudinal study of self-assessment in a capstone course with 239 students. In agreement with previous studies [11], students appreciate the task of assessing their own and others' work. The students in the study are very good at evaluating their capabilities, the difference between the self-assessment and teachers' final assessment was about 10%. It can be difficult to assess individual contributions accurately when running collaborative design projects. Using a studio-based approach, with formative feedback throughout the process, individual oral and written presentations, and support from self-assessment, team feedback and teacher discussions, there is a much higher certainty that students are assessed accurately. For the 2023 edition of the course, the teaching team have decided to redesign the team assessment and follow the advice from Boud [6] to involve the teams in identifying standards and/or criteria for good documentation. The new procedure involves students discussing and iterating high-level objectives and success criteria for their project work before using them for team assessment.

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LANDSCAPE METAPHORS FOR BACHELOR DESIGN STUDENTS' IDENTITY AND VISION DEVELOPMENT

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ABSTRACT
Professional identity and vision (PIV) development is important for students to shape their educational path and future careers. It is important for students to be guided in this PIV development, but writing a PIV text could be challenging for many. To supplement the text-based approach of PIV writing, we explore how a physical toolkit using landscape and other metaphors could help students in their PIV development and reflection. Two case studies were conducted at Eindhoven University of Technology. Data collection was done through an adapted professional identity scale supplemented by semi-structured interviews. We conclude that our toolkit is most suitable for final-year bachelor students and those beyond this stage in their degree, and that the main use of the toolkit lies in its reflective nature.

Keywords: Professional identity, professional vision, design students, design education, metaphors

1 INTRODUCTION
For students in many disciplines, especially those with less well-defined career paths, Professional Identity and Vision (PIV) are tools to give direction and purpose to an educational path. Identity is a contemporary issue in engineering [1]. At Eindhoven University of Technology, a technical university in NW Europe, Professional Identity is defined as the student's identity as a designer, based on factors such as personality traits, interests and competencies [2]. Vision is defined as the student's beliefs about the future of design, its function in society and the role of design research [3]. All Industrial Design (ID) students at this university are expected to write and update their PIV regularly, but many bachelor students struggle developing and reflecting on their PIV. The university organises workshops and regular feedback moments from coaches, but these methods focus on a student's PIV as a textual document. Students—including in disciplines such as design, where non-text formats are common—could benefit from other ways of engaging in PIV development and reflection, for example through visualisation exercises, or ways to physicalise thinking through constructing models. Data physicalisation is an emergent research area concerning the disciplines of data visualization and design, where a 'physicalisation' is "a physical artifact whose geometry or material properties encode data" [4]. 'Constructive physicalisation' is the practice of fabricating personal physicalisations to encode data [5] or promote reflection [6]. Research has shown that visualisation and physicalisation exercises can assist design students in exploring design topics [7] or facilitate learning and accelerate the learning process (e.g. [8, 9]). In this paper, we examine how one such physicalisation method could help ID students develop their PIV. We build on an existing toolkit, Thinking With Things (TWT) [10], in which a workshop format focuses on metaphorical physicalisations (building on [11]) that use the physical properties of materials to investigate the qualitative nature of lived experiences. As such, it is suited to the target group of ID students familiar with using materials to express themselves, and the topic of PIV as the method focuses on lived experiences. We therefore ask: "How can the 'Thinking with Things' toolkit support bachelor ID students in creating and reflecting on a design-based PIV?"

1.1 Professional Identity and Vision Scales
Several studies have investigated professional identity across different fields, using various scales. The revised 25-item Professional Identity Five-Factor Scale (PIFFS) [12] and the Professional Identity Scale [13] are utilized in this study. Questions about self-efficacy and the professional as a role model make parts of PIFFS a suitable scale to assess students' PIV. The Adams et al. scale focuses on the sense of belonging within the profession. From the PIFFS scale nine questions covering four relevant factors

were used in this study. An additional nine questions from the PI Scale study were added. Two questions rated on a seven-point scale were added that inquire how participants experienced the toolkit's value with regard to the development and reflection on their PIV respectively. ("How would you rate the usefulness of this workshop for developing your professional identity and vision" and "How would you rate the usefulness of this workshop for understanding your own professional identity and vision compared to the professional identity and vision of others").

2 METHOD

2.1 Workshops

We ran two workshops, with a total of 14 Industrial Design students, described in sections 3 and 4. Before and after each workshop, students completed the questionnaire outlined in section 1.1. Workshop 1 was with nine first-year bachelor students (B1), typically aged 18–20, while Workshop 2 was with five final-year bachelor students engaged in their Final Bachelor Project (FBP), typically aged 21-25.

2.2 Planning

Table 1. Planning of activities for the workshops with duration for the B1 and FBP groups

Activity	**Duration in minutes (B1)**	**Duration in minutes (FBP)**
Welcome and participants filling in the informed consent form	1	1
Filling in the pre-workshop questionnaire	2	2
Introduction to the TWT method and its connection to PIV	2	2
Discussion of PIV in groups and building the landscape	21	15
Sharing and discussion of created landscapes between groups	19	9
Connective stage introduction, and start building	14	13
Sharing and discussion of created connections between groups	13	8
Performative stage introduction with new dynamic materials	13	removed
Sharing & discussion of performative stage results between groups	5	removed
Post-workshop questionnaire filled in again by the participants	4	4
Group interview with the participants	6	16
Interview with the PIV tutor *(B1 only)*	5	n/a

Table 1 shows the planning and the duration of each part across the two workshops. The adjustments and differences between the B1 and FBP workshop are further elaborated on in Section 4.1.

2.3 Quantitative Data Analysis

Responses to the first 18 questions of the questionnaire (comparing pre- and post-workshop responses) were analysed using the Wilcoxon signed ranks test. The same test was applied across the different categories. Due to the low number of participants in each group, the results of the Wilcoxon signed ranks test (and any other statistical analysis of the questionnaire) were deemed unreliable. Instead, responses were briefly explored per participant, observing their developments per question/category, and were compared to the interview responses to see whether results matched up. Median scores for each of the two final questions were calculated to give an impression of the workshop's effect on PIV development and reflection. These results were primarily utilised to contextualise or confirm the qualitative findings gained from interviews and observations.

2.4 Qualitative Data Analysis

Observations were written down covering comments made, specific behaviours or actions, and the descriptions participants gave of their TWT creations. Along with the interviews they were analysed through open coding. Two researchers coded these into one codebook each, which were then discussed, leading to a single codebook where multiple codes could be assigned to a single piece of text.

Krippendorff's alpha [14] showed an inter-coder reliability of α = 0.4018. A third coder made decisions in places where the previous two coders disagreed, to create the final code assignments. Due to the subjective nature of the topic and the low inter-coder reliability we cannot reliably draw any quantitative conclusions from the codes, and thus they were only used as a method to make sense of the many textual transcriptions.

3 WORKSHOP #1 - FIRST-YEAR BACHELOR STUDENTS

3.1 Structure

The first workshop involved the three stages used in the TWT format: *Topological (Landscape)* - Creating a shared landscape through physical metaphors such as mountains, bridges, and trees; *Connective* - Creating connections in the landscape representing relations through materials such as yarn, wire, and more; and *Performative* - Creating new models where dynamic transformation and reflection is represented through temporal materials (which change in some way over time) such as lights, marbles, and dissolving sugar cubes. The workshop took 105 minutes with 20 minutes of construction per stage, the remaining time being used for instructions and for participants to present their creations.

Figure 1. (Left) Laying out materials for the workshop. (Center) Using rivers to connect different parts of a landscape. (Right) Sugar cubes represent the absorption of knowledge

3.2 Procedure

The workshop was hosted as part of a PIV course lecture where nine B1 bachelor students and one tutor were present. In preparation landscaping materials were laid out on a table as shown in Figure 1. Participants signed an informed consent form that made clear that participation in the study was optional even if participation in the course was compulsory. Students discussed their PIV in groups, and then filled in the questionnaire described in section 1.1. In groups of three, students went through the three stages of the workshop, filled in the same questionnaire afterwards, and were interviewed to gain more information about their experiences. The tutor was interviewed separately. These interviews were transcribed through edited transcription corrected for repetitions, corrections, and interruptions. No participant identifiers were applied in the transcriptions as the nature of the interview made it difficult to identify speakers and connect them to the questionnaire responses.

3.3 Interviews and Observations

Materials were leading in the build process. Participants were attracted to materials first and subsequently projected meaning onto them. Exploration of materials inspired participants to incorporate these into their landscape. Participants noted the prominence of organic shapes in the kit: “I feel like this steers you very much in the nature direction. [...] we’re a group of engineers. It would be really good to have some robot shape or similar things to have more ways to represent that.” One student noted how the limited representation in the kit sparks creativity: “A human/person was the only thing I looked for. but it was good that it wasn’t there.” Another indicated that the limitation of the kit causes force-fitting to the objects available: “The fact that you can choose from certain things may also influence that you adapt [your PIV] a bit.”

The Landscaping stage was easily the most appreciated. “Normally you write it down. But now I’ve made this thing around it and it’s easier to remember.” Participants regularly used landscape elements to create connections, as can be seen in Figure 1. While no specific comments were made on this, the use of connections within the landscape may have affected the connective stage.

The Performative proved confusing: “I felt like the last exercise was a bit random,” and “I think I struggle to come up with something that represents the past and now.” The purpose of the Performative

stage was questioned, and participants noted that it did not add anything compared to the first two stages. Creations in the third stage addressed learning experiences or design processes rather than the individual identity and vision of participants (see Figure 2).
The group felt the workshop did not immediately give them any new insights that contributed to developing their PIV. The most notable value was in providing a new way to address and construct a PIV, as noted by the tutor: “I think [the workshop] provides development [...] in a better understanding that you can make abstract things like personal identity, vision, more visual, and that you can maybe apply [making things visual] on other subjects also.” One participant noted that it helped them have a concrete view of their PIV, implying the value was more affirmative than constructive.
However, students indicated that the workshop helped them reflect or share. “[I]t helped me to reflect because I discussed it and now I have more ways of thinking about it.” One described that “[y]ou are thinking of it visually first and then you can find the words. It becomes easier to describe your PIV.” A sense of belonging is a common thread. In comments relating to sharing and group work, ‘ease of sharing’, ‘understanding the other’ and ‘relating to the other’ are recurring themes.

4 WORKSHOP #2 - FINAL-YEAR BACHELOR STUDENTS

4.1 Structure

During the B1 workshop, the students showed decreased motivation during the Connective and Performative stages. In addition, the students seemed to engage with the exercise too superficially to produce meaningful developments for the participants. The Performative stage also proved confusing. Another workshop was organised for FBP students to assess whether the Landscape and Connective stages are valuable to bachelor students overall, comparing B1 students to final-year FBP students. The participating FBP students were working on their graduation project during the period they participated in the workshop and were expected to have developed their PIV further.

4.2 Procedure

5 FBP students attended the workshop. These students were recruited through voluntary sampling. Compared to the B1 workshop, no PIV tutor was interviewed, and the performative stage was not included, as reception of the Performative stage was poor among B1 students. The workshop time was 1 hour. Two groups were formed (a group of three and a group of two). No changes were made to the data collection or analysis process.

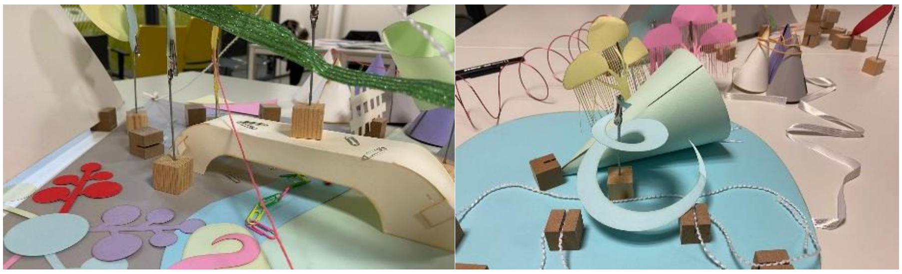

Figure 2. (Left) Connecting ‘helping people’ and people themselves using a paperclip chain. (Right) Using a water metaphor to represent pitfalls and opportunities in PIV development

4.3 Interviews and Observations

Like with the B1 group, materials were leading in creating a narrative, as one participant describes: “You see [an object] and you think, ‘what can I do with it?’ instead of ‘this connection is here, I am going to the table and get something that fits it.’” When given a box of coloured paper clips to attach connective materials to their landscape, one FBP participant immediately started linking paper clips into a chain, seen in Figure 2. This student described directly identifying with materials and relating them to their identity: “I was drawn to things that interested me, and they were automatically in line with my identity itself because it’s what I like that I’m picking up. [...] I could make it to represent something, but it doesn’t mean it means the same thing to everyone.”
The prominence of organic shapes was again noted in both positive and negative ways: “there’s a lot of variety in trees, but then there’s no houses or anything.” One participant noted that “It also maybe makes you more creative due to the limitations.” Material properties are mentioned as a way to express the

nature of a connection mad during the second stage: “[w]e use different kinds of materials for the connections and those define the kind of connection.”

The Landscaping stage was favoured, much like with the B1 group. “I think this workshop really helps to put your PV into a daily life because it’s [a] landscape, and you start thinking about what's in a landscape that fits with my PIV.” The Connective stage had mixed responses as some felt it was redundant: “I didn’t totally get making the connections between the parts, as the landscape connects it in its context itself already, I think.” Another noted that “[t]he connections that we made at the end in the second part maybe were more forced [...] that made us lose the bigger connections that you already thought of in the first half.” Some felt that addressing connections directly pushed them to think deeply about the nature of the connections: “[F]or me I thought about it, and then created new meaning because you talk about it.” Figure 2 shows connections that emerged during this stage.

Participants specifically noted that no new insights regarding the development of their PIV were gained: “I didn't really find it constructive. You recognize parts that you may already have incorporated, and I personally didn't recognize new opportunities or parts.” Students did note the workshop’s communicative and reflective value: “I have quite some difficulty communicating my PIV to others. Reflecting in an abstract way on it is helpful to me,” and “[t]his exercise kind of forces you to think about how you are with respect to other designers.” When asked about the group setting, one participant described that “[...] it’s nice to experience the overlap between you and the others. You get ideas from each other or take over some.” Another noted that “[the exercise] tells you how you could be related to people who have completely different perspectives of design or a completely different vision.” This, much like the B1 responses, emphasises the workshop’s value for bonding and relating to peers.

5 DISCUSSION AND CONCLUSION

Overall, the Landscape stage was received most favourably by all participants. While the Connective stage was sometimes seen as redundant, it still produced interesting insights for participants through the properties of the materials offered. We recommend that the Connective stage should be included in the workshop, but the Performative stage should be excluded. The Performative stage mostly left B1 students confused. Participants mention that the exercise felt random and struggled to create something that reflects both the past and present. These participants also noted that the third stage did not really bring them anything the first two stages could not cover. This sentiment was recognised by the researchers when observing the participants building their landscapes; temporal components of PIV such as its development over time were naturally incorporated without the need to encourage this in the temporally oriented Performative stage.

During the workshop, FBP students were able to discuss and be critical about each other’s PIV more than B1 students. B1 students have less to reflect on as they are still creating the foundation of their PIV. However, during the interview some B1 students mentioned how the toolkit made it easier for them to engage with their PIV compared to working with text. We speculate that FBP students—as one might expect—have a more well-defined identity and vision, allowing them to look critically at each other’s PIV and the landscapes created. This may contribute to giving the FBP students a sense of belonging in their chosen profession during the workshop. Moreover, the materials used were leading in the emerging narratives, as students look at shapes, material properties and colours to explain their PIV. They are inspired by attractive materials and create a story around it afterwards. During the workshops, all the students addressed what they found important in their PIV and created different narratives within the landscape that reflect on the present and future of their PIV and designer experience. This finding suggests that the value of the TWT toolkit for PIV application lies mainly in creating a shared narrative where students reflect on their PIV in contrast to that of others and develop their sense of belonging through this.

5.1 Limitations and Further Research

We observe some limitations in our study. Firstly, this approach to PIV development might not be suitable for all students, as it requires students to think in metaphors and discuss fairly abstract concepts (identity/vision) using physical objects (landscape elements). Additionally, the selection of objects could strongly guide the type of narratives that students construct.

Secondly, FBP students self-registered or were invited to take part in the study, while the B1 students participated as part of a PIV course. This sampling difference could have influenced the results. A follow-up study should employ identical sampling methods for the different groups.

Finally, since we adapted both the structure of the workshop (removing the Performative stage) and the participant criterion (FBP rather than B1) at the same time it becomes difficult to identify confidently which variable caused the change in results between the two workshops. Future research may want to isolate the change in audience as the only changing variable between sessions.

Future work should explore whether the method could be applicable to students from other backgrounds than design. We believe that the design discipline places heavy emphasis on developing a unique skill set and vision, which may be less prevalent in other disciplines. Exploring whether our workshop setup can contribute to PIV development in other fields would be interesting.

Our workshop setup as described in this study is currently being integrated into the PIV curriculum of Eindhoven University of Technology. Further experiments will continue with a broader student group, in collaboration with the coordinators of the PIV programme.

We conclude that the use of the toolkit in PIV workshops lies in creating shared narratives where students reflect on their PIV in contrast to that of others. Through this they develop a sense of belonging to the profession, making the TWT workshop very suitable for FBP students (and potentially for master’s students).

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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RESPONSIBLE DESIGN FOR (NOT WITH) HARD-TO-REACH USERS

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ABSTRACT
Urgent new priorities, ranging from social inequalities to the climate emergency, are creating new roles for design professionals. Design education responds, fostering responsible design through collaborations with new kinds of stakeholders, technologies and expert advisers.
This is an example of such a multidisciplinary, design-led, innovation project, with some student output and learning outcomes, reflections and subsequent developments. In a Masters course that emphasises personal purpose for change-making in the world, and alongside other units focusing on designing with ethical, environment and social responsibility, this 3 week unit tasked MA/MSc students of Innovation Design with applying artificial intelligence and machine learning technologies to human rights and humanitarian issues. The project brings expert insights, inspiration and guidance from fields of AI and ML, but also international criminal law & war crimes, collective intelligence, gamification, gender-based violence and people trafficking. The process and outcomes are shared as examples of rapid learning from an intensive activity, with little technical instruction and no primary user research.
Here the designer acts for users and stakeholders outside of the consumer-corporate dynamic. The beneficiaries may be victims of human rights abuses and cannot ethically be included directly in research or testing by students. Despite this, the project demonstrates the value of secondary research and empathic methods alone. In an open-ended qualitative survey, responding students expressed appreciation for the opportunity to explore such challenges, and for a sense of purpose, reward or validation in their efforts to create futures that are inclusive and just.

Keywords: Humanitarian, crime, human rights, legal

1 CONTEXT AND BACKGROUND
As is clear from the urgency of the themes in this conference, we are in a time of rapid change in design priorities, and these must be reflected in design education. Only a decade ago we would expect to facilitate student collaborations with corporations and design agencies, exploring new ways to meet customer needs, with the implicit and often unquestioned goal of commercial profit. Now, outside academia, urgent new priorities range from social inequalities to the climate emergency, combining with a widespread recognition of design's tools and methods in broader spheres of application [see e.g., 1, 2], to create important new roles for design professionals. These roles are reflected in design education, fostering responsible design through collaborations with new kinds of stakeholders, technologies and expert advisers. This may coincide with a shift from technical colleges to universities, "towards research and critical enquiry, with more of an emphasis on how design can contribute in more substantial ways to human well-being" [3].

In a previous account I discussed the challenges of experiential learning [4] for innovation design, for complex and risky contexts. Examples were shared of contrasting possibilities [5], in which benefits of immersive learning (such as increased empathy and contextual understanding) weighed against the challenges (such as risk of physical or emotional harm) involved in first-hand encounter. In the safer, studio-based example there was little likelihood of serendipitous insights, and all contextual understanding was indirect, reliant on designers' empathic ability and limited to what information expert contributors considered relevant.

Building on these examples I share a similar challenge here, in which students had neither first-hand experience of the context, nor could they make any user contact, for practical and ethical reasons.

Framed within a Masters course that emphasises responsibility and personal purpose for change-making in the world [6], and alongside other units focusing on designing with ethical, environment and social responsibility, this unit tasked MA/MSc students of Innovation Design with applying artificial intelligence and machine learning technologies to human rights and humanitarian issues. Concepts were developed in an intensive 3 week block after the briefing talks.

The project brought expert insights, inspiration and guidance from fields of artificial intelligence (AI) and machine learning (ML) within the institution, but also contributions from guest experts in international criminal law & war crimes, collective intelligence, gamification, gender-based violence and people trafficking. The structure and outcomes are shared as examples of rapid learning outcomes from an intensive activity, light on technical instruction, and without direct user engagement.

In this, as for many of the services and products conceived by students of this programme, the designer's intent is for users and stakeholders outside of the consumer-corporate dynamic (whereby a desired service is paid for in a transaction, with money or attention). Just as in commercial design, a user-centred approach is understood to be necessary for any hope of success [see e.g., 7, 8, 9], that is, in order to conceive and develop a response that meets the needs of those affected by the issue in question. More than this though, explicit inclusion of affected people is considered a moral and ethical duty incumbent on the providers. To borrow from humanitarian innovation discourse: "demonstrating how the rights and interests of affected people are respected in an innovation process ought to be a minimum standard." [10]. This respect applies to the intended end users, but naturally also to anyone involved in the research and testing phases of design and implies careful consideration of privacy and other risks. We might even question our 'right' to expect such participation; "designers must account for the structural conditions of users' lives, as they may have safety, accountability, and political implications" [11]. At a macro perspective, one critique argues that the "technological fix" offered by "do-good design performs the grassroots ideological work of neoliberalism by promoting market values and autoregulation." [12]

Commonly in this teaching environment, as in many others, students are encouraged or required to demonstrate user involvement in their developing designs wherever possible. In this project though, affected people cannot ethically be included directly in research or testing by students, because of potential risk to themselves or the students. They may be victims or potential victims of traumatic circumstances and abuses. This constraint was compounded with other limitations of time and technical knowledge. Still, with other taught projects focusing on user research, prototyping and technical testing, the emphasis of this unit was on rapid creative responses, based on a rich briefing of inspiration and information.

2 PROJECT BRIEF, STRUCTURE AND FORMAT

In this project, students were challenged to develop creative, human-centred design proposals, grounded in technical feasibility, exploring how communities and legal experts might use big data and AI to provide a deterrent against, and increase convictions for, human rights abuses.

The unit was run twice on consecutive years, in blended format due to post-COVID restrictions. Participants worked in pairs and threes, in person where possible. The project challenge was introduced in a full briefing day, introduced by the unit tutors then followed by talks from a range of contributing subject matter experts (see Acknowledgements) on the subjects of AI, ML, collective intelligence and big data models and applications; human rights and the digital/data landscape; human trafficking and gender-based violence; gamification for humanitarian context.

Students were reminded of ethical requirements for taught PG students, and especially of the need for caution, to avoid risk of emotional or physical harm to themselves and others.

As second year Masters students they were expected to define their own process, with access to tutorial support every few days and to college technical services. The assessed outcome was in the form of a short video or viva presentation explaining the concept, its background and rationale, and the team's process.

3 SAMPLE WORK, DESIGNED OUTCOMES

Students produced a range of concepts, focussing on different areas in the remit of the brief, mostly digital or service innovations. Indicative examples are shown in Figure 1.

1. *J{AI}NE DOE* provides assistance for law enforcement officers against sex trafficking. AI-

generated victim personas are automated and scaled to engage online groomers.

2. Gathering secure evidence against intimate partner violence, *Cepi* can record audio and summon help without putting the user at risk. Trigger words start recording and summon law enforcement.
3. *Project X*: An anonymising camera app protects protesters while still allowing public sharing. Fictitious faces are AI generated to replace real people and are shared anonymously on a public account and in a secure repository. Can be reversed for use in legal cases.
4. *ClearCard*: Enables asylum seekers to match and source agreed facts from third party evidence, in support of their claim. In the UK, many refused asylum claims are appealed, and around ¾ are subsequently granted.
5. *Uncover*: a browser extension to spotlight likelihood of indentured labour to consumers and suggest alternatives.
6. *Seen Voices*: art-based mental health support system and qualitative data gathering tool for refugee children.

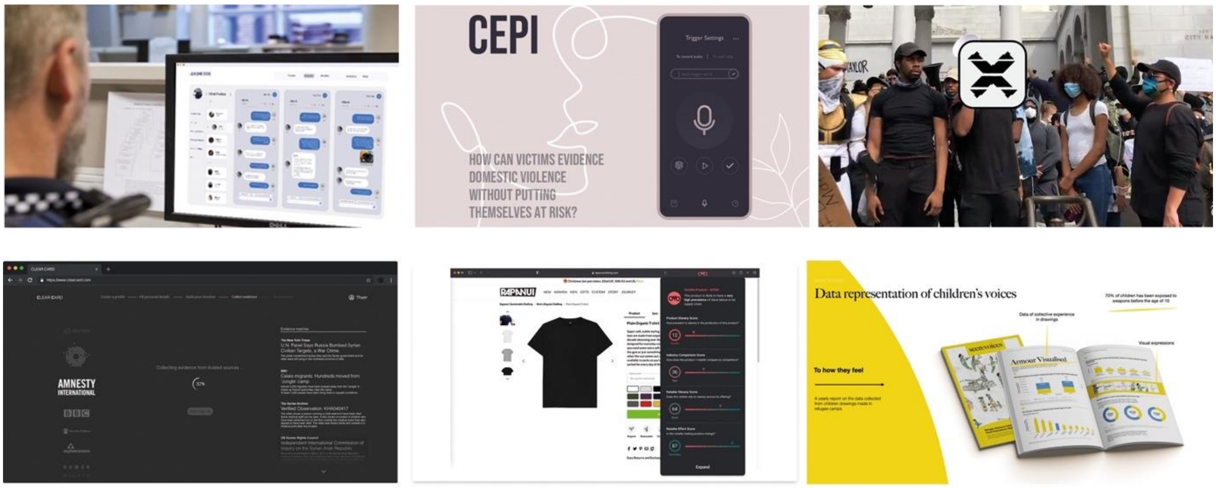

Figure 1. Example concepts (top L-R) J{AI}NE DOE, Cepi, Project X, (bottom L-R) Clear Card, Uncover, Seen Voices [credits: redacted]

(Credits: Grishma Bhanderi, Seetharaman Subramanian, Harrison Tan, Jingyi Li, Axel Pietschker, Ziqq Rafit, Nikolaos Grafakos, Millicent Wong, Tong Lo, Ahad Mahmood, Alasdair Grant, Yilin Wen, Arnau Donate Duch, Weixinyue Peng, Aura Murillo Perez, Louise Lenborg Skajem, Luqian Wang)

4 STUDENT REFLECTIONS

Some months after the project, a simple, open-ended questionnaire survey was made with all participants. Nine students responded in some depth, with feedback indicating a strong appreciation for the opportunity to explore such challenges, for the engagement with passionate and committed actors outside of the product/ service industries, and for a sense of purpose, reward or validation in their efforts to create futures that are inclusive and just. Several projects have been carried on by students for further development, and students have expressed a desire to work in related fields after graduation. The following are indicative extracts.

4.1 What were the best parts of the project?

For most, the input from ‘real’ experts working in challenging issues was inspiring and brought a greater degree of authenticity to the brief. The subject area itself felt meaningful and important. The briefing days were very full, with a lot to deal with emotionally as well as intellectually:

> “Intro talks with big range of speakers were super engaging and interesting (maybe bit intense though)”
>
> “The best part of the project for me was hearing from experts in the field talking about the difficulties faced with images and information capture of human rights violations in places such as the middle east, and how technology was helping the researchers and lawyers verify true information and media from fake and doctored images. It greatly inspired [our brief] and the approach we took.”

> “The guest talks during the first two days uncovered a lot of opportunities.”

The technology introduction was useful and thought-provoking for some:

> “Thinking high level about how to apply machine learning to help social issues felt fulfilling and gave us a lot of energy to push the project.”
>
> “…using technology to solve some of the media capture and verification issues faced in documenting human rights violations…was a scenario I had not considered before… For all the negatives that automation in technology can bring… someone somewhere is finding a good use for a new technology.”

For others it felt too superficial to be meaningful, though many were excited to learn about collective intelligence, in relation to crowdsourcing and processing evidence:

> “Understanding the principles of collective intelligence especially”.
>
> “I was new to this approach and found it really inspiring (and actionable).”

4.2 What were the weaker parts of the project for you as a learning experience?

Most frustration was expressed about the short duration and consequent reduced opportunity to connect with any stakeholders – not only users but other gatekeeper experts:

> “Lack of opportunities or time to establish relationships with direct users and their care takers made it difficult to validate the viability of our idea.”

To get deep enough into the context…

> “It felt reductive not being able to consult anyone when designing such a system, but that is the nature of sprint projects. That said, the issues and challenges faced by asylum seekers are harrowing but are also fascinating subject area that demands more attention.”

…or to go more deeply into the technology.

> “I would have deeply loved to actually work with AI/ML engineers to whip up a prototype or develop a working concept. I think it [is a factor of] the short duration of the course, and I would have loved to work on this project for longer.”

While some were frustrated by the time limitation, one student enjoyed the pace:

> “I really enjoyed the speed, and the boundaries of the project. Being pushed to look through the lens of collective intelligence was a really interesting approach, even if our final concept didn't reflect it as much as it could have.”

Another reflected that a simple introduction to the technology might be enough to stimulate creative exploration leading to valid concepts, and to inspire further work.

> “It's a good start and guidance. A superficially understanding is enough for us to inject into this field and aroused my passions to keep exploring.”

4.3 How did you feel about the issues and contexts you worked with?

As noted above, students were motivated by a sense of the importance of the issues. Some were unsettled by their scale and gravity and feared being out their depth. They recognized the complexity of the challenge, and that such subjects need to be approached without hubris, but with sensitivity and humility:

> “Meaningful but challenging, the experience of designing interventions in these contexts can be very dark at times.”
>
> “It certainly gave us motivation, and it felt a lot like this is what [the MA] is all about: designing for these difficult global topics. It pushed me into areas I was interested in but might not have gone to normally. [I] felt very nervous of making missteps, oversimplifying problems, not understanding the space, offending people etc. I am not sure I am qualified to design here.”
>
> “There are a lot of stakeholders involved and… other specialists are in better position to help. As designers it was a challenge in the early stage to identify what is an appropriate place for us to intervene.”

For one group this influenced their concept direction, and they chose to focus on a consumer-facing tool:

> “We had to decide whether to interact with the victims of modern slavery… or pivot to something that was focussed on end-consumers (people/contexts we were familiar with) but would have a net-result of helping reduce slavery… This decision was partially based on a conversation with someone more familiar with [indentured labour], who made us realise how badly we understood the situation.”

4.4 How did you get around not being able to work directly with end users?

While drawing heavily on secondary research, many teams also made indirect stakeholder contact "by talking to experts who have worked with the end users before", though for some, time didn't allow.

> "We reached out and spoke with people that did work directly with vulnerable at-risk people - in our case human trafficking victims."
>
> "Having tutorials with guest tutors was useful too as it gave us feedback from different realistic perspectives. But… we had to work with information from second hand research and make assumptions based on what we know in the area of children and mental health issues."
>
> "We tried… but timing and schedule did not allow. Instead, we relied on [public] video interviews with the target group and reports from advocacy organisations."
>
> "We could access YouTube testimonials of protestors in Hong Kong, who were using social media platforms to document their lives and educate their fellows on how to organise and protest. We were also able to leverage some excellent coverage done in the US following the Black Lives Matter protests and the impact of technology on the protests and how police would use tech to harass and impede the protestors."

5 CONCLUSIONS

Despite the limitations of time and depth of exploration, the project demonstrates the value of secondary research and empathic methods, and simplified technical understanding, in generating early-stage concepts. As such, it doesn't claim to lead to robust proofs-of-concept, but instead suggests the creative value of freedom from these requirements. We should not avoid these kinds of issues just because they are technically and ethically challenging. Responding students expressed appreciation for the opportunity to explore such challenges, hinting at the possibility of doing so in future, while remaining mindful of their responsibility, and healthily cautious of the dangers of over-simplification, whether at the user interaction level, or the socio-political system.

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ASSESSING COMPETENCIES FOR SUSTAINABILITY IN ENGINEERING EDUCATION – A CASE STUDY

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ABSTRACT
Achieving a sustainable and climate-neutral world is a social and complex technological task. Engineering designers therefore play a vital role as their technological developments may require the use of resources on a large scale. However, these developments are also driving factors for the transformation towards a more sustainable future.
This transformation requires capable, specifically trained engineers who are able to take sustainable aspects during the product development process into account. This in turn requires basic knowledge in the field of sustainability, which students should be introduced to in engineering education.
In this paper we examine competency models for sustainability described in the literature and which can be directly adapted for engineering education. Using the example of the course "Sustainable material selection and product development" at the University of Rostock, Germany, we present a way to assess competencies of sustainability in engineering education to evaluate the impact of our course design.

Keywords: Engineering education, product design, sustainability, core competencies, competence models

1 INTRODUCTION
The global population is projected to exceed 9.7 billion by 2050 [1], contributing to a steady increase in the extraction of raw materials, which could surpass 100 billion tonnes annually by 2030 if the current trend persists [2]. This unsustainable resource consumption, coupled with a lack of recovery frameworks, is exacerbating the scarcity of resources and putting an immense burden on global ecosystems [3].
Engineers have a critical role to play in the transition towards a circular economy, given that the technologies they design consume resources on a large scale and drive social change [4]. Consequently, they bear a responsibility to consider the ethical and sustainable dimensions of their work from the outset of product and process development. Despite this, prospective product designers often receive inadequate training on sustainability issues, as studies reveal that only a small number of engineering programmes in Germany incorporate such topics into their curricula [5]. To address this gap, the authors developed a course at a German university, described in a previous paper [6]. The course deals with various topics and techniques along the product life cycle and combines different, mostly interactive, teaching approaches. The examination performance is a semester project in which the students develop a sustainable solution for an engineering problem. The goal is to equip students with relevant skills and mindsets to actively contribute to a more sustainable future.
The aim of the present study is to evaluate the effectiveness of the developed course and analyze the competency areas where it has the highest impact.
This leads to the following research question:
- Q1: What are the competency areas where we have the most significant impact?

For which we must first answer the following two questions:
- Q2: What are the available competency models that categorize relevant competency areas for sustainability in engineering education?
- Q3: How can we assess the improvement in competency areas?

1.1 Competency Models for Sustainability in Engineering Education

Starting from the question of whether the module serves its purpose, we searched the literature for competency models in the field of sustainability for engineering education.

Desha et al. [7] present a view of global organisations such as the International Engineering Alliance (IEA), which is developing universal sustainability standards for engineering education. The authors also draw on examples from the US and Australia to illustrate how these standards are put into practice at the national level. However, implementation remains vague or is limited to certain engineering disciplines. Looking at Germany, there is also no comprehensive regulatory framework for the integration of sustainability topics in engineering education and even well-respected accreditation agencies like the “Accreditation Agency for Study Programmes in Engineering, Informatics, Natural Sciences and Mathematics” (ASIIN e.V.) have yet to provide specific guidelines on this matter [8].

It is becoming apparent that the development of competency models for sustainability in engineering education is an ongoing process, and various scientific studies have been conducted to understand the competencies required for sustainable engineering practice, including those by Svanström et al. [9], Segalàs [10], Quelhas et al. [11] and Beagon et al. [12]. The reviewed papers provide valuable insights into the competencies, highlighting the complexity of the field and the need for multiple perspectives. However, despite some overlap, discrepancies exist in the competencies found in the reviewed literature, including differences in the number of competency areas identified and variations in the terminology and descriptions used.

It is evident that although efforts have been made to develop competency models for sustainability in engineering education, there is currently no widely adopted or universally recognized model for this field. Furthermore, the question remains of how the identified competencies can be assessed in our course.

As the development of competencies for sustainability in engineering education is still in its early stages, there is currently no prevalent or universally accepted competency model for this domain. As a result, we consulted general competency models for sustainability, with the model by Wiek et al. [13] being particularly well-regarded and highly influential [14]. This model identifies five competency areas, including

- *Systems-thinking competence* (Evaluate a sustainability challenge holistically.)
- *Anticipatory competence* (Generate potential scenarios for how the problem might evolve in the future.)
- *Normative competence* (Thoroughly evaluate a sustainability-related issue and its surrounding context.)
- *Strategic competence* (Develop intervention tactics aimed at preventing unfavourable outcomes and achieving sustainable goals.)
- *Interpersonal competence* (Foster collaboration with researchers from other disciplines, along with key stakeholders in government, corporate, and civil sectors.)

1.2 Assessment of Competencies

As described in section 1.1, there is no universally accepted competency model for sustainability in engineering education. Therefore, we searched for literature on how competencies in the field of sustainability can be measured in general. Redman et al. [15] published a comprehensive literature review "Current practice of assessing students' sustainability competencies" in 2021. Due to its recognition, Wiek et al.'s competency model served as a basis. In their work, the authors differentiate eight different types of assessment tools from a total of 75 studies, namely scaled self-assessment, reflective writing, focus group/interview, performance observation, regular course work, concept mapping, scenario/case test, scenario/case test and conventional test. The review of the advantages and disadvantages of each tool by Redman et al. [15] showed that the scaled self-assessment was the most common method. In the review, the scaled self-assessment by Savage et al. [16] was chosen as a representative example with a precise description, whose paper also includes the complete questionnaire based on the competency model by Wiek et al. [13].

2 RESEARCH APPROACH

2.1 Study Design

This study investigates the development of students' sustainability competencies in the course "Sustainable material selection and product development". This course is part of the engineering education at the bachelor level, but can also be attended by master students. As shown in the previous sections, there is currently no model for sustainability competencies that is tailored to engineering education. For this reason, we utilized the widely recognized competency model by Wiek et al. [13].
For our survey, we used a multi-part self-assessment procedure where the students rate their agreement to pre-defined competencies statements. We choose this tool because it produces quantitative data which we can analyze and it is easy to administrate and scale if needed.

2.2 Test Procedure

For this survey, we chose the scaled self-assessment tool developed by Savage et al. [16]. The survey tests the students' self-assessment and competence to perform an action in the five areas provided by Wiek et al. [13]. To detect the changes over the semester we conducted a pre-test on the first day of the module and a post-test about 12 weeks later at the end of the term. The post- test contains an additional second part, where the students can state, why they rated a question differently or the same as in the pre-test. It is a pen and paper test consisting of 15 Questions which were translated into German - three questions each on the five sustainable competence areas. One of the questions (original question 5 - see Figure 1 b) was too broad for our purposes, so we removed it. Additionally, we slightly adapt the questions to subjects that are addressed in our course, as proposed by Redman et al. [15]. For reasons of space, we are not able to display our entire questionnaire. But this can be requested from one of the authors if necessary. Another adjustment was made to the Likert-scale. We increased this to a scale range of 5, with 0 (disagree) and 5 (agree) to allow students to take a neutral standpoint. Excerpts from the questionnaire are shown in the Figure 1 below.

a)

I feel confident and competent to: 1= Disagree 2=partially agree 3=neutral 4 partially agree 5= agree	disagree	Partially disagree	neutral	Partially agree	agree
1. Articulate a vision of a just and sustainable society					
2. Account for individual and cumulative social, environmental, and economic implications of a decision or process.					
3. Analyze complex problems drawing from multiple discipline					
4. Assess the resources available and necessary for an action					

b)

I feel confident and competent to: 1 = Disagree 2 = Partially Disagree 3 = Partially Agree 4 = Agree	Response 1st	Response 2nd	1. Explain why your responses did or did not change.	2. Do the questions represent each competency for you? Are they good indicators? Explain.
Normative				
1. Articulate a vision of a just and sustainable society				
14. Understand your own strengths and weaknesses as a sustainability leader				
5. Collectively assess the current and future states of social-ecological systems				
Interpersonal				
9. Motivate positive change in others				
11. Pursue collaborative approaches to problem-solving				

Figure 1. Excerpts from the questionnaire by Savage et al. [16]: a) pre- and post-test; b) second part of the post-test

Figure 1 a) shows the structure of the pre-test and post-test with the mixed individual questions. The right section shows the structure of the second part of the post-test. Here the tasks are sorted by competencies. The students enter their scores and give a self-assessment for possible changes. Additionally, they could state their most significant learning in the course. There was no time limit for the test performance, neither in the pre- or post-test. The students were given verbal instructions and then a printed questionnaire on which the answers were recorded. A randomly generated 3-digit participant number was used to assign pre and post-tests. Immediately after the post-test, students were again given the results of their pretest and completed the second part of the post-test based on the difference in scores (Figure 1b).
Participation was voluntary and did not influence the course evaluation. At any time, the participants could stop the test or withdraw their consent.

3 RESULTS

The course was composed of ten students (five bachelor and five master students). It was made up of different disciplines mainly mechanical engineering but also biomedical and civil engineering. One student only participated in the pre-test and one student did not answer all questions resulting in a final sample size of n=8.

Below are presented the results, clustered by competency area according to Wiek et al. [13]. In Figure *2*, the light green bars represent the average self-assessment of the students on the Likert-scale for each question in the pre-test. The light blue bars show the corresponding result in the post-test. The dark grey bars show the difference between the average points of pre- and post-test with corresponding numerical values. These values represent the increase in self-confidence of the students ans therefor our courses impact regarding the competencies.

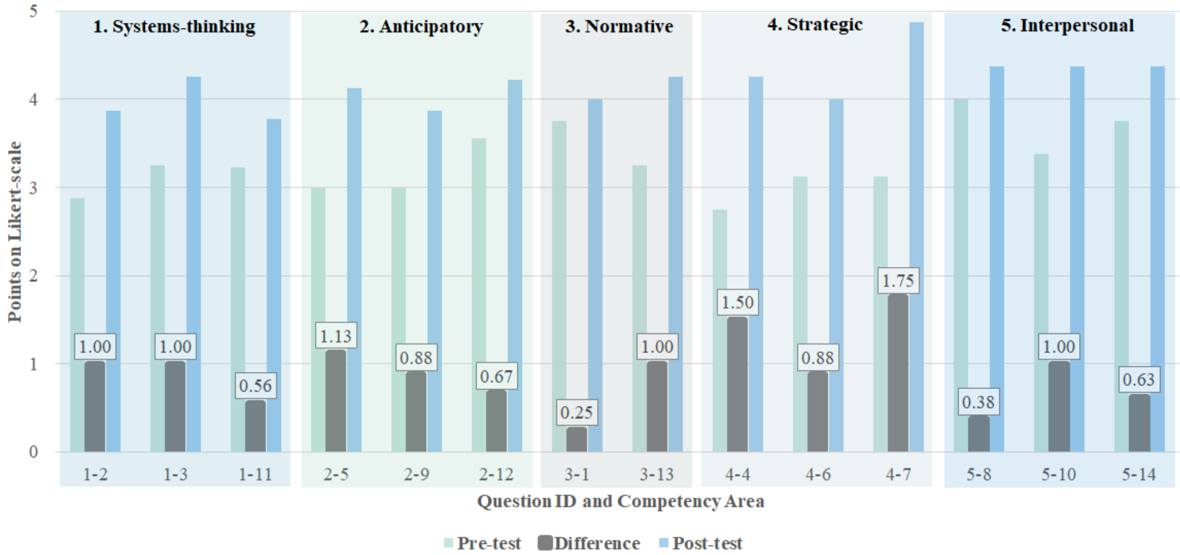

Figure 2. Point distribution in pre-and post-test and average differences between results

Within the individual competence areas, certain variations in the difference are evident, although the initial levels are relatively high for all questions. It also gets obvious that the students' self-assessment of their respective competence has increased on average throughout. When the competency areas are combined as shown in Figure 3, the following additional trends can be observed:

In the area of normative and interpersonal competence, the students' self-assessment at the beginning is relatively high. The lowest is in the area of strategic competence. Systems-thinking and anticipatory competence fall in between. In contrast, it is noteworthy that self-assessment regarding strategic competence in the post-test not only increased to a similar level as the other areas, with a maximum difference of Δ=1.38 points on average. It is now rated as confidently as interpersonal competence, with an average assessment of pre4 = 4.38 points.

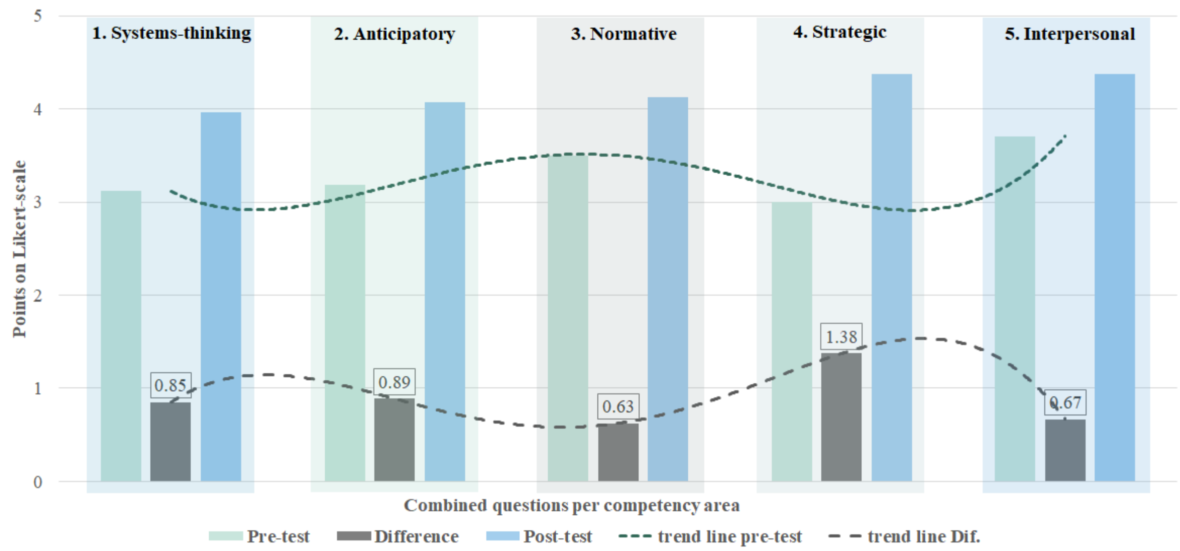

Figure 3. Point distribution per competency area in pre-test (including trend line) and post-test including differences between results (including trend line)

In the post-test statements regarding the most important learning outcome, the following points were particularly highlighted by the students: Practical tools for assessing the sustainability of solutions in product development, not only qualitatively but also quantitatively; a combined approach from the perspective of different disciplines; and most notably, the hands-on application of the learned material in their semester projects.

4 DISCUSSION AND CONCLUSION

The study showed that we have achieved a general increase in self-confidence in all areas of competence with our course. The basic effectiveness has thus already been proven.

Furthermore, it was noticeable that the participants were particularly self-confident in the areas Normative (pre3=3.50) and Interpersonal (pre5=3.71) and the areas System-thinking (pre1=3.12) and Strategic (pre4=3.00) were in last place. We achieved the greatest improvement (Δ= 1.38) for this competence area "strategic" with the worst starting position. Of course, we expected the greatest development potential in the lowest areas but we even managed to rise above the other competence areas with a final self-confidence level of post4=4.38.

This corresponds to the contents of our course. It has an informative character and is intended on the one hand to establish systems thinking and on the other hand to provide tools for application in different problems and tasks along the product development process. With these tools, students are enabled to achieve self-set sustainable goals for their design and to evaluate design decisions in terms of sustainable impacts.

So, the results of the study show that we have the biggest impact in the area of the learning objectives of our course. If we include the verbal explanations of the participants, it becomes clear once again that the practical application of the various tools in the different design phases has contributed to this.

The multi-self-assessment test with the basic questionnaire provided by Savage et al. is easy to use and to adapt but of course still subjective. An additional limitation is due to our small sample size.

5 OUTLOOK

We plan to continue the study in future runs of the course. Additionally, part of the data has not yet been analyzed. For instance, an examination of the individual self-assessment regarding changes in the students' pre- and post-test in the context of the competency areas could lead to further adaptability of questions in our course. Additionally, we propose an expansion of the analysis to additionally include a more objective method as proposed by Redman et al. [15]. This is important to ensure the reliability and validity of the results, as well as to provide a more comprehensive understanding of the studied phenomena.

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DESIGNING A NEW CURRICULUM: COMPETENCY-BASED ON DESIGN EDUCATION

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ABSTRACT
Competency-based learning is oriented to educate by the implementation of challenges where students must demonstrate that they have achieved and generated knowledge through the development of applied skills.
Design education has been significantly transformed in the last ten years thanks to the integration of new perspectives and seeking a more forward-thinking vision. This shift is motivated by the recognition of Design's desire to develop a most responsible approach.
In response to the need for a curriculum renewal based on competencies and a future-oriented vision, this paper outlines the process of creating a Competency-Based Learning curriculum that has been designed over five years framing the Tec21 "Design Programme," which reflects an approach to shaping the future of design education in Mexico.

Keywords: Curriculum renewal, design education, competency based learning, educational innovation, professional education

1 INTRODUCTION
The need to design a new curriculum arises from the constant change where the current world is subjected. The requirements to be constantly updated to avoid the obsolescence of academic programmes and to be at the forefront of educational models, generated a concern about how to design new curricular plans that are aligned with the macro, meso and micro global trends, and with the prevailing need to offer professional level studies to students who seek to be prepared for the challenges they will face upon graduation.
Design schools are in constant evolution of the new epistemic stances as well as the pragmatic approach that they must consider when implementing a new pedagogical model.

2 DESIGN EDUCATION
Design Education is a concept complex to explain, in a classic educational point of view, it demands that there is a design practice related to a pedagogic strategy in which students and teachers are enrolled into a design project studio to arise their conceptual, procedural and attitudinal skills in order to solve a design problem and develop a strategic and innovative solution by creativity. But recently the concept had to expand according to the challenges in which the planet lives and the current ways of thinking that constantly evolve.
The designers in training will be using tools and design processes that will be focused more in solving responsibility and impact problems through social innovation and transitional strategies to embrace a sustainable and regenerative future [1].

2.1 Context
Formal Industrial Design education was founded based on the historical necessity of having products that may cover the several human needs trying to be produced by iterative manufacturing processes and developing an aesthetic code that bonds with the emotional necessities of the users. Nowadays the design schools are more concerned about the human factors and leading into an era in which the Design is a solution to critical problems that have to be solved by future designers.
Many universities have migrated from Industrial Design denomination to only Design, giving opportunity to various manifestations that not necessarily end in tangible products but can be extended

to all those products that do not contain a materiality. They are teaching more topics related to sustainability and social innovation where technology is the constant in the equation.
In an exercise carried out by UNESCO between 2005 and 2014, educational centres from different levels and from different countries were studied to determine which are the elements that guide education towards a sustainable approach within learning spaces.
The main findings in this study were that a sustainable development pedagogy must be given through collaborative learning, community participation, remote learning and with a focus on research. With this, it is proposed to trigger the development of social leadership among students with the intention of implementing projects among the communities [2].
Meyer & Norman propose that Design education should broaden its perspectives as a discipline of relevance and impact on the planet. Apart from the learning of the design process, there must be a lateral extension towards disciplines of basic, social and natural sciences. This integration of other sciences does not displace the artistic approach that has always defined design, on the contrary, these new visions will potentiate the designer's capabilities [3].

2.2 Competency-Based Learning

The present day Design schools should aim for a pedagogical approach that goes beyond the mere construction of products in laboratories. Instead, the focus should be on developing students' abilities to make decisions in uncertain situations [4]. This involves providing students with a variety of tools, techniques, and methodologies to effectively communicate their ideas and construct innovative solutions. By doing so, Design schools can guide students in achieving the optimal versions of their solutions.
The adoption of Competency-Based Learning in Design Education is not a recent concept. Its purpose is to create opportunities for empowering the classroom and fostering interactive participation among students, moving away from a passive educational model. The teachers are focused on bringing better learning experiences by applying the theoretical knowledge in “challenges” designed by a trainer partner who is an external entity allied to redirect the educational process towards the attainment of proven proficiency and the practical utilization of knowledge and abilities in real-life contexts. These challenges help to build secure and reliable assessments that are focused to map the competencies and accomplish them by outcomes that the students will be building at an individual pace in different levels of mastery [5].
According to Tecnologico de Monterrey, a competency is “the conscious integration of knowledge, skills, attitudes and values that allows one to successfully face both structured and uncertain situations and that may involve higher order mental processes”[6] .
The students must demonstrate the development of disciplinary and transversal competencies in order to accomplish the challenge which is the center of the educational efforts. The main objective of a competency is to integrate conceptual, procedural and attitudinal knowledge aimed to consolidate the learning process depending on the area of study.
The career disciplinary competencies are focused to shape the professional profile of students enrolled in a particular programme, starting from the major stage of their curricular programme. These competencies are integral to the acquisition of knowledge, skills, and attitudes that orient a competent professional in their field of expertise [7].
In a study conducted by a group of teachers from the Singapore University of Technology and Design, the authors explore through qualitative research guided by interviews to Design educators from different countries, the importance to integrate theoretical and practical knowledge framing recent competencies that are developed by current Design schools during the COVID-19 crisis [8]. The study identifies several key competencies necessary for Design education, including empathy, creative research skills, collaboration and teamwork, communication, leadership, and responsibility.
The importance of integrating competencies on the Design educational models goes beyond traditional academic learning, enriching the hard and soft skills development. This model promotes practical learning, exposing the students to experiences linked with training partners, such as external organizations and companies, that promote the leverage of these competencies on the innovation and creative processes to solve Design problems with a fresh perspective. This approach ensures graduates are prepared to address reigning and future challenges bringing impact solutions.

3 TEC21 EDUCATIONAL MODEL

Tecnologico de Monterrey is a private university founded in Monterrey, Mexico and is constituted by several campuses along the country. In 2012 there was an institutional statement to transform the educational model in order to bring new tools to teachers and students framed by the new challenges that were scaffolding due to the profile of the new generations with the aim to train 21st century professionals [9]. Is in 2019 when this new educational model starts to be taught in the classrooms and brings new structures and goals to be accomplished.

The Tec21 educational model offers new possibilities for the curricular structure, empowering the students to make decisions all along the eight semesters that conform their programme. It is based in four key components [10]:

- Challenge Based Learning
- Customization
- Memorable Experience
- Inspiring Professors

4 CREATIVE STUDIES

The necessity to offer undergraduate introductory programmes was aimed by Tecnologico de Monterrey in order to concentrate common multidisciplinary knowledge areas freshmen students. In the case of the School of Architecture, Art and Design, “Creative Studies” is the name of the programme.

The Creative Studies programme offered by the institution spans over two semesters and focuses on designing and producing projects and multidisciplinary solutions for various professional fields. The primary objective of the programme is to help students develop skills related to handling various creative languages aimed to solve innovative projects. These skills enable students to be better equipped to handle challenges and solve problems in their respective minor and major fields.

Creative industries are a significant contributor to the economy, making it crucial for students to develop skills related to creative topics.

The Creative Studies year programme is structured as follows:

- **Elective courses.** Provide students the flexibility to explore specific areas of interest and broaden their knowledge and skills beyond the core curriculum.
- **Area courses.** Essential curriculum courses that will provide the core perspective of the Creative Studies introductory programme. The main topics are:
  a. Creative Methodologies
  b. Research Methods
  c. Arts & Design History
  d. Applied Creativity Project Studios
- **Tec Weeks.** Immersive week courses where the students develop specific competencies to strengthen their commitments to ethics and citizenship.
- **18th Week.** It is the final week of the semester and is oriented to be a reflective ending moment in which the students will be analysing their progress and how they are developing their competencies.

After the students finalize the introductory Creative Studies phase, they will start their selected major programme where they will complete their programme [11].

5 TEC21 DESIGN PROGRAMME

The Design programme at Tec21 was structured considering the new roles that the designer must face in future challenges, focusing on themes of regenerative design, social innovation and a dynamic strategic approach to solve the wicked problems.

The term "Industrial" was removed from the name of the programme to offer a wider range of possibilities to the Design practice and not limit it to the pedagogical guidelines of the discipline or the type of product that can be developed. The epistemic approach is more holistic and seeks to develop solutions based on project didactics from the pragmatic perspective.

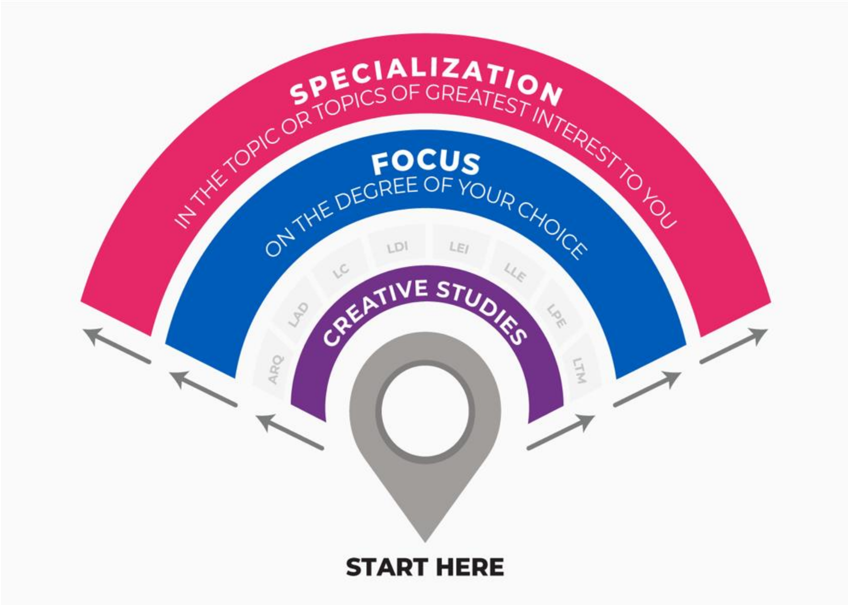

Figure 1. Tec21 Creative Studies Stages [12]

The educational model is made up of two semesters of Creative Studies, two semesters of the Major Programme in Design (Focus) and four semesters of the Minor Programme in three study areas (Specialization):

- **Product Design**. Seeks to strategically and innovatively develop physical products through research, 2D and 3D communication, and validation oriented to study people and their social and cultural environment, as well as the planet in pursuit of its regeneration.
- **Design & Technology**. The exploration of new modalities of use of new technologies and intelligent materials is proposed with the intention of serving the human being focusing on the well-being of people and the planet.
- **Visual Design**. Explores to design and develop graphic and visual communication products whose configuration can be analog or digital, starts from the strategic study of the user experience through interfaces that allow them to have immersive experiences.

Introductory Program	Major Program	Minor Program
Creative Studies	Architecture	
	Digital Arts	
	Design	Product Design Design & Technology Visual Design
	Communication	
	Musical Technology & Production	
	Educational Innovation	
	Spanish Literature	
	Journalism	

Figure 2. Design Programme

There are four disciplinary competencies that must be accomplished by the students, in synthesis, they are a simplified version of a Design process resume in 4 steps. The idea is that the student develops his soft and hard skills by understanding every phase in a project and realizing that there is a different level for each competency to achieve the highest range after they finished the 8 semesters programme.

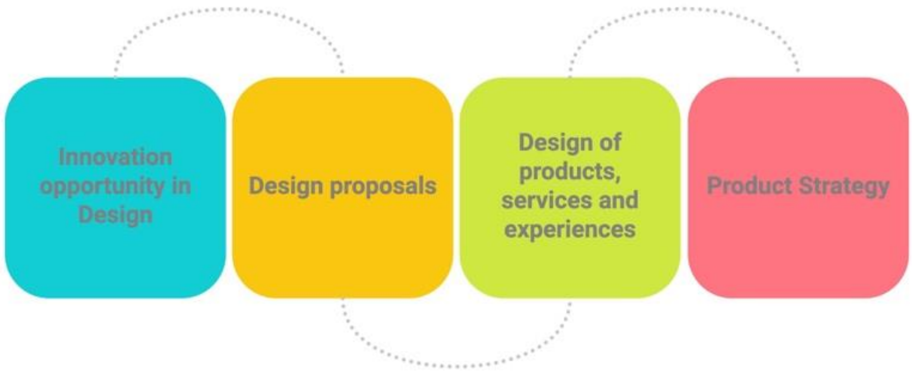

Figure 3. Tec21 Design Programme short name competencies

Major Competencies

1. Define innovation opportunities, applying design methodologies, centred on the person and their context.
2. Conceptualize design proposals based on the functional, constructive, expressive and sustainability requirements of the project.
3. Design meaningful, high-impact products, services and experiences.
4. Design the implementation strategy of the product, service or experience in public and private contexts.

Minor Competencies

Product Design

5. Develop design strategies in organizations that respond to business, institutional and community challenges in a local and global environment.
6. Design new avenues of innovation by strategically managing the design process for products, services, and experiences.

Design & Technology

7. Develop strategies that generate technological products, with a humanist vision and responsibility.
8. Design viable technological products that are committed to the expectations of stakeholders.

Visual Design

9. Design experiences and visual interfaces that respond to specific user needs.
10. Direct multidisciplinary creative projects focused on the development of graphic, digital and interactive products.

The new perspective of the Design School at Tecnologico de Monterrey is focused on preparing students for current and future challenges in both local and global contexts, where Design plays a key role in addressing issues that impact the status quo of individuals and the planet. Competency-Based Learning will enable students and teachers to engage in environments that facilitate the application of knowledge in real-life situations.

6 CONCLUSIONS AND FUTURE DIRECTIONS

The new Design schools have become strategic incubators for creative and artistic expression, with a high level of technological exploration, a sense of sustainable responsibility and a look towards social innovation. Design schools must direct their approach through community participation between students, teachers and society.

Technological exploration is crucial to be available to guarantee that the tools and instruments are always updated and ready to be applied, the Designers must become agents of change and see themselves as people who live on a planet that still has hope.

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THE ROLE OF GRAPHIC DESIGN IN PROMOTING SUSTAINABILITY AND ETHICAL RESPONSIBILITIES AGAINST GREENWASHING

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ABSTRACT
The aim of the study presented is to provide an overview of the current understanding and approach of graphic designers towards environmental sustainability. Within this study, we include a survey exploring the awareness among graphic design students and staff of this topic and discuss integrating sustainability within current professional practice. The topic of 'greenwashing' is also reviewed and discussed.
Advertising invests heavily in profiling their target market to understand their culture, values, motivations, and language. They use this knowledge to predict purchasing decision-making and behaviours, but little or no consideration appears to be given to the environmental impact of their products. The outcomes of this study will be incorporated into teaching resources that will be made freely available to students, other educators and practising graphic designers.

Keywords: Environmental sustainability, graphic design, greenwashing

1 INTRODUCTION
With the growth of the human population and worldwide industrialisation, sustainability is risen in importance for society and designers. In 2015, the general assembly of the United Nations (UN) defined a universal call to action entitled *Transforming our World: the 2030 Agenda for Sustainable Development*. The agenda aimed to address these major challenges, in order to achieve a better and more sustainable future for all [1, 2]. The roadmap for agenda delivery groups the issues into 17 Sustainable Development Goals (SDGs), each one describing a targeted action to mobilize global efforts to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030.
The topic of Sustainable Development has been a focus for academic research [3-9], NGOs such as Greenpeace [10], Oxfam [11], WWF [12], Food and Water Watch [13], and the Natural Resources Defence Council (NRDC) [14]. Despite the work and progress achieved, thanks to the effort of environmental organisations, individuals take action through small pressure groups or movements and undertake protests. The movement of Friday for Future [15, 16] is actively protesting for concrete actions from the governments of several nations. Although several goals have been defined it can be argued that no concrete action to realise those goals has taken place, or it is taking place too slowly [17].
The examples above show that the desire for a renewed and concrete approach to sustainability is not involving big organisations only, but it is a primary concern and direct interest for individuals, people belonging to the younger generation *in primis*. According to this stream, as well as the ethical implications for this topic, it is our assumption that the education system has the duty of investigating and addressing the topic in a more and more concrete manner within the context of Higher Education.

1.1 Environmental Sustainability
The definition of sustainability, or better Sustainable development, is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [18] However, as mentioned by the work of Scoones, "Sustainability must be one of the most widely used buzzwords of the past two decades. There is nothing, it seems, that cannot be described as 'sustainable': apparently, everything can be either hyphenated or paired with it" [19].

This statement makes clear how this topic should be carefully investigated, in order to provide the right understanding and weight of this field and its real applications with a focus on our own sector (e.g., Graphic Design).
The three aspects of sustainability cover: Environmental, Social and Economical (Figure 1). In order to keep this wide topic as focused as possible, this paper will focus on Environmental sustainability.

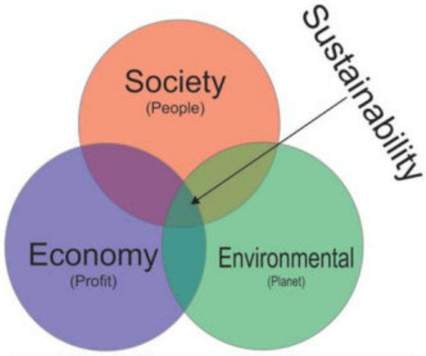

Figure 1. Interlocking circles model of sustainability by Lee, 2014 [20]

1.2 Environmental Sustainability in Graphic Design

As discussed in the literature, research exploring the relationship between Graphic Design (GD) and sustainability shows that this sector is still emerging. There is a need to provide a clear link between the role of a Graphic Designer and sustainability. We aim to explore more about that and to create some guidelines to be applied for Higher Education in the field. Literature shows that the topic of GD for environmental sustainability includes discussion mainly regarding the **press process** [21], **packaging design** [6, 22-4], **icon design** [9, 25] and **communication design**: e.g., emotional design, [26-28] and consumer awareness. [3] Whilst critically reviewing those sectors, the importance of the phenomena of Greenwashing (GW) is frequently mentioned.
As mentioned in the UN plan, companies must address and disseminate non-financial information on their environmental impact and produce material to educate customers [2]. This guideline, combined with the genuine concern from the market around the topic, has led several companies to add their visual communication accordingly. However, the question is, are the companies doing it efficiently? Also, are these organisations truthful in communicating that information? The phenomenon of GW is then the mainstream response to incorrect and dishonest behaviours from companies to mislead the understating of users for their own profit. Introduced in 1986, the term GW designates 'the act of misleading consumers regarding the environmental practices of a company or the environmental benefits of a product or service' [29].
The role of GD in addressing and in designing responses to the trend of GW is fundamental for the sustainable needs of our planet. GD Students' and graduates' experience is likely to be on the client-focused requirement to deliver financial rewards, without addressing the current environmental crisis, pollution, biodiversity loss, or climate change. Responsible design, focusing on environmental sustainability, could be better integrated within GD in higher education. It is our assertion is that this situation has to change through raising awareness of students on this topic and co-creating a set of guidelines to incorporate responsible design within their design process.
Through an online survey, we aimed to understand the current awareness of GD undergraduate students and GD staff of GW, sustainable development goals and responsible design. We set this data collection conscious that some of the students, which were the main respondents, might not be fully aware of the topic, considering that no specific lecture or module around those thematic was run. Within this investigation, our goal was to discover the main gap and collect qualitative feedback on their understanding.

2 METHOD

The aim of the survey was to provide a better understanding of the current awareness, among GD students and GD professionals, of sustainability - and how to integrate it within current professional practice. The data collection also investigated the phenomena of GW. A mixed methods approach was taken. By including both closed-ended and open questions, we could collect statistics to monitor the overall understanding of the topic as well as the individual personal feedback of the students.

2.1 Data collection

The data collection consists of an online survey questionnaire advertised to all Loughborough University GD undergraduate students and staff members. The participation in this survey (which was active for one working week only) was on a volunteer basis. The data collection took place in early March 2023. The survey was anonymous to collect unbiased feedback, with time taken to complete was 5-7 minutes. Student participants were aware that completing the survey had no influence on their study grades. The data collection was approved by the University of Loughborough Ethical Committee in March 2023 (ID: 13122).

2.2 Questionnaire Structure

The questions included both closed and open-ended for a total of 9 questions, plus demographic information including gender, age, nationality, occupation (for students as well) and if any GD work experience was present.

3 RESULTS

3.1 User Demographic

A total number of 62 feedbacks were collected and included:

- Gender: 41 Females (66.1%), 18 Males (29%), and 3 (4.8%) other gendered
- Age: 56 participants (90.3%) between 18-25 years old, 1 between 26-35 (1.6%), 3 between 35-45 (4.8%) and 2 between 45-55 (3.2%)
- Nationality: British: 47 (75.8%) and 10 other nationalities (24.2%) including Belgium, Brazil, China, Cyprus, Hungary, Italy, Malaysia, Poland, Romania, South Korea, Taiwan and Zimbabwe
- Occupation: 41 GD students first year (66.1%), 12 second year (11.3%), 5 third year (8.1%), 2 placement students (3.2%) and 7 Teachers/Lecturers/Staff (11.3%)
- Experience: 55 participants (88.7%) never worked as a graphic designer/visual designer in a company (for more than 6 months)

3.2 Environmental Sustainability and Greenwashing

1. 61 (98.4%) of the participants heard about sustainability.
2. 55 (88.7%) are interested in the topic of environmental sustainability
3. 40 (64.5%) participants were already introduced to the topic of GD and Sustainability – within this percentage, 36 (58.1%) by the university, 5 (8.1%) by placement and 10 (16.1%) by external platforms. 22 participants (35.5%) stated they have never been introduced to the topic and 3 (4.8%) by other sources.
4. 31 (50%) participants have heard of GW before, whereas the other half have not. When provided the definition of GW within the survey, 38 respondents provided qualitative feedback (i.e., a personal statement) on the topic.
5. When asked to rate between 1 and 5 the impact that GD has in the promotion of sustainability, 0 selected ‘no’, 4 (6.5%) ‘minor impact’, 18 (29%) ‘some impact’, 30 (48.4%) ‘large impact’ and 10 (16.1%) ‘high impact’.
6. When asked how GD can realistically impact the promotion of environmental sustainability, 53 (85.5%) respondents selected ‘educating customers’, 40 (64.5%) ‘disseminating information’, 21 (33.9%) matched ‘working for sustainable companies only’ and 1 (1.6%) wrote ‘*All above and developing stand through Design Activism*’.
7. When asked how graphic design can reframe the perception of sustainability within society, participants provided 26 qualitative responses. E.g., participant ref. 106661059: “*By accurately representing the level of eco-friendliness of the product*”.

4 DISCUSSIONS

This paper explored the topic of environmental sustainability and greenwashing within the field of Graphic Design. Our data collection involved mainly 1-year-GD students and shows that the majority of them are conscious of the role of their subject for the topic. However, the study also shows that only half of the participants were formally introduced to the topic of Sustainability, and within that sub-group, only half rated the University as one of the channels for that. Little knowledge or confused understanding was also recorded for the field of GW, showing that only a minority are aware of it.

By considering the feedback from the first and second questions, we can state that the topic of sustainability is well-known among participants and that the majority were interested in the topic. However, considering that only slightly more than half of the respondents stated to have been introduced to the topic, and that within this percentage only half of the respondents' included 'University': we believe that more formal education about sustainable design for GD students should take place within the GD University program.

The knowledge of GW was not well known within the group, as only half participants stated they knew what it was. 7 of the qualitative comments, some students were supportive of GW, showing a lack of understanding of the term. For example, participant ref. 106658808 states: "*I think that it is an effective way of showing sustainability through design".* When stating comments related to GW related to their values as a graphic designer, some of the comments included, for instance: "*GW overall takes away from the values of sustainability"* (Ref: 06660788), *"it is false advertising"* (Ref: 106661059), *"seems eco-friendly (...) when in reality it is not"* (Ref: 106661724), *"sounds harmful towards sustainable practice"* (Ref: 106661564), *"irresponsible"* (Ref: 106661788) and *"It needs to be readdressed in uni curricula"*(Ref: 106665630).

Data from the question 'How much impact do you think Graphic Design has in the promotion of sustainability?' show that the majority of the GD students see *some*, *large* or *high levels* of impact. Considering this factor, we value the fact that designers see clearly how their work can affect this sector. Awareness is present, which is an important factor to be accounted for in an effective education process in Higher Education. GD students saw the importance of 'Educating customers' and 'disseminating information related to sustainability' as two important issues.

When commenting 'How can graphic design reframe the perception of sustainability within society'*?* some of the qualitative comments included, for instance: "*Make sustainability look more interesting by creating thoughtful imagery"* (Ref: 106658808), *"pushing education about how to be more environmentally friendly"* (Ref: 106658815), *"advertisement" (x2)* (Ref: 106660477 and 106661709), *"By accurately representing the level of eco-friendliness of the product"* (Ref: 1 06661059), *"infographic"* (Ref: 106661564) *and "design activism"* (Ref: 106675044). Those responses suggest that the GD participants understand the concept of Responsible design for environmental sustainability and that they included ethical considerations for the design approach. In alignment with the literature review, solutions such as infographics and advertisements can be considered tangible responses.

4.1 Limitations

The main limitation of this investigation resides in the gap in responses between experienced GD users (staff members and placements) and GD UG students, where the first category was a significant minority. Also, within UG responses, most of them were coming from first-year students. This factor might explain why the topic of GW was not well-known among them, as this population is less experienced in the field.

5 CONCLUSIONS

This research highlights the need for GD students to better understand this topic and explore how their future work could provide potential solutions. We aim to address the lack of knowledge on environmental sustainability and GW within the field of GD within future actions, including the design of subject-specific content within GD modules. This may include exploring with the students a set of design strategies to meet Environmental sustainability through visual and education design practices to educate customers' behaviours. Second and third-year students can be encouraged to do more research in the field, plan the design development and create design strategies and visual touchpoints. As part of the creative process, they could prose new processes and visual solutions to promote sustainability and fight GW.

Additionally, we aim to expand our literature review and repeat the current data collection in the future; with finalist GD students, with junior designers and with senior practitioners; to test if implemented knowledge in the field changes the statistics presented in the paper. The outcomes of this study and the following study will be incorporated into teaching resources that will be made freely available to other educators and industries. We welcome further discussion and debate as well as collaboration with other academics and industrial partners to present a balanced and pragmatic pathway to raising awareness of responsible design alternatives to current training and practice.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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PERSUASIVE DESIGN TO ADDRESS SUSTAINABILITY IN ENGINEERING EDUCATION

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ABSTRACT

Sustainable design is becoming a common practice since there is a global interest in protecting the environment and enhancing the health and well-being of human beings. However, sustainability is a complex issue. The relationship and balance between environmental, economic, and social demands during the design process require an understating of systems, environment and human behaviour, and business perspective. Consequently, there is a need to provide engineering students with design knowledge and tools for sustainable design. One tool is persuasive design since this approach influences the users' behaviours and decisions. The change of behaviour of consumers might have a significant impact on waste, contamination, energy and materials consumption, and other sustainability indicators. This paper presents a list of strategies for persuasive design and a pedagogical model to introduce them to engineering design education. The pedagogical model focuses on applying persuasive design for sustainable design and its ethical dimension.

Keywords: Persuasive design, sustainability, engineering education, behaviours, pedagogical model

1 INTRODUCTION

Sustainability issues like resource scarcity, contamination, and global warming have become more relevant in recent years. Especially when those issues threaten all human activities and compromise the sustainability of societies as we know them today [1]. As main actors, academics, industry, and governments have proposed many approaches, including methodologies, design rules, new manufacturing processes and technologies, and manufacturing and supply chain policies, among others, to face such sustainability issues. However, it is common to find that none of those efforts have enough impact in the mid and long-term since consumption habits still follow a primarily throw-away culture.
As an interesting approach, the persuasive design of a product can address issues that modify consumers' behaviour. This design method involves design principles that promote more sustainable lifecycle management of products by users. Nevertheless, persuasion is commonly more related to marketing strategies, and awareness campaigns about products and services and rarely is covered by engineering curriculum.
This article proposes a list of persuasion strategies arranged in a pedagogical model oriented to address two main issues: the first one relates to the inclusion of self-awareness and sustainable behaviour in engineering design courses. And the second one aims to prepare future engineers to implement persuasion into their product designs to promote more sustainable product consumption and use patterns.

2 PERSUASIVE DESIGN

Persuasive design is a strategy to shape human behaviour by incorporating specific features in products or services. This concept is highly related to psychology, communication, and marketing to create designs that appeal to users' emotions, desires, and motivations. Commonly, it is employed to design elements, such as colour, functionality, shapes, layout, and intractability, to persuade users toward a specific behaviour or goal. As stated by Fogg [2, 3], the primary purpose of persuasive design is to enhance consumer motivation, abilities, and behaviour triggers. These can be achieved by creating user experiences that are engaging, easy to use, and emotionally appealing.

2.1 Persuasion principles for engineering design

According to the existing literature, more than 30 principles of persuasion can be used in both products and services to influence consumer behaviour [4, 3]. However, many of those principles are primarily geared toward the use of technology or services and do not apply to products. Therefore, a list of the most applicable principles of persuasion for engineering design is proposed and summarized in Table 1

These principles were selected considering the FEEL-THINK-DO model around sustainability and how to implement them during engineering courses and prepare students to apply them in future product designs. Thus, persuasion principles in Table 1 provide easiness to being included in an academic context (e.g., big names, logos, research, tailoring) to support data and facts and their relationship with current sustainability issues. Emotionality was also considered to promote motivation and awareness. (e.g., pathos, Kairos). Nevertheless, it is possible to include other principles according to the requirements of the pedagogical goals.

Table 1. List of persuasive principles for engineering design. Based on [2, 3, 4]

N	Principle	Definition
1	Big Names	Use experts and important people to support your argument
2	Logos	Use logic, number, facts, and data to support your argument
3	Pathos	Appeal to the user’s emotions
4	Kairos	Build a sense of urgency for the cause
5	Research	Use studies and information to make your argument seem more convincing. Use words, graphs, tables, illustrations
6	Tunnelling	To lead users through a pre-determined sequence of actions or events, step by step.
7	Tailoring	To provide features that are specific to the individual to enable better a particular behaviour (customize)
8	Suggestion	People are more likely to engage in an activity when it is closely related to what they are currently doing.
9	Conditioning	To reward a target behaviour

3 PEDAGOGICAL MODEL FOR PERSUASIVE DESIGN

This article presents a pedagogical model that outlines the principles and methods based on persuasive design to facilitate learning experiences in engineering students around sustainability issues and provides a structured approach for designing, delivering, and assessing educational activities to measure and make decisions on the learning-teaching process.

The pedagogical model aims to motivate and engage students in actively addressing sustainability challenges during their undergraduate studies and, therefore, future engineering work. By incorporating sustainability into engineering design education, students can better understand the importance of sustainable practices and their impact on society and the environment. In addition, the pedagogical model seeks to empower future engineers to apply their knowledge and skills to create innovative and sustainable solutions, fostering a culture of responsibility, awareness, and stewardship within different engineering fields.

The methodological approach proposed covers the FEEL-THINK-DO model and the different levels of Bloom´s taxonomy to ensure a robust response from students regarding the factor or persuasion. As a novel element, this approach considers persuasion applied to students and by students implementing sustainability aspects. Table 2 synthesizes the main components of the proposed pedagogical model.

3.1 Implementation approach ON STUDENTS

The first approach of the pedagogical model is centred on students. Persuasion principles are included in pedagogical activities following the FEEL-THINK-DO model and progressively considering Bloom’s taxonomy to create an incremental development of competencies during the courses or modules. Figure 1 shows the approach for persuasive design ON STUDENTS, and Table 3 maps the FEEL-THINK-DO model to the engineering topics, learning resources, and principles of persuasion.

Table 2. Summary of main components of the proposed pedagogical model based on persuasive design

Component	Description	For the proposed model
Learning Objectives	Goals that students are expected to achieve	• To increase self-awareness about sustainability issues • To identify and implement sustainability indicators to measure the environmental impact • To apply design tools to reduce or improve sustainability indicators in design projects. • To implement persuasive principles in their design projects to persuade others
Instructional Methods	Approaches used to deliver the content and teach students	• Lectures • Case studies • Design projects • Role-play activities
Assessment Methods	Tools and techniques used to measure student's learning and progress	• Project presentations assessed through rubrics. • Surveys about persuasion impact on students • Surveys about persuasion impact on others
Learning Resources	Materials and tools used to support the educational activities	• Documentaries • Sustainability reports, including indicators. • Online learning platforms
Learning Environment	The physical and social context in which learning occurs	• Classroom design oriented to collaborative work. • Design thinking-based approach
Feedback and Evaluation	Feedback activities aimed to improve the learning and assess the effectiveness of the pedagogical model itself	• Group-based feedback • Co-evaluation and self-evaluation during the presentation of projects

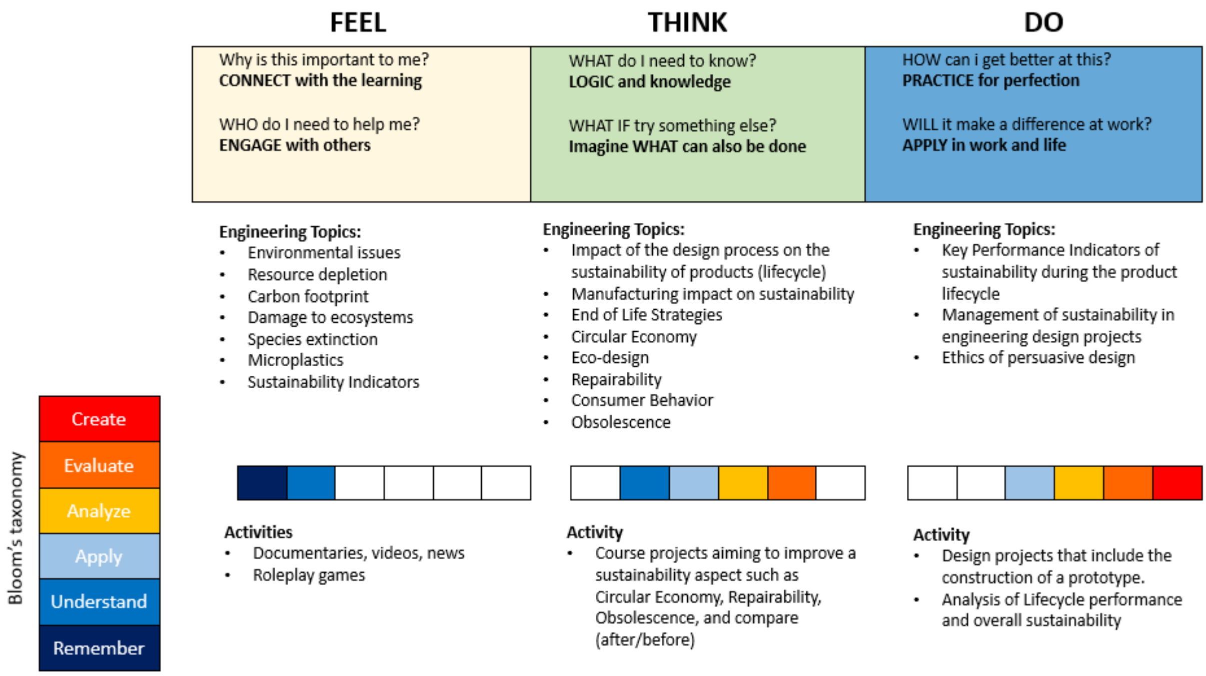

Figure 1. Approach for persuasive design ON STUDENTS

Table 3. Persuasion principles recommended for each engineering topic of the proposed model

Main Process	Engineering Topic	Learning resources recommended	Persuasion Principles from Table 1
FEEL	Environmental issues	Videos, Video Documentaries, Sustainability reports about resource depletion, species extinction, global warming, interviews to experts, news	1,2,3,4,6
	Resource depletion		1,2,3,6
	Raise of Carbon Footprint		1,2,4,6
	Damage to ecosystems		1,2,3,4,6
	Species extinction		1,2,3,4,6
	Microplastics		1,2,3,4,6
	Sustainability indicators		1,2,6
THINK	Design impact on product sustainability	Lectures, documentaries, sustainability reports, scientific articles, self-diagnostics about the environmental footprint	1,2,5,6
	Manufacturing impact product sustainability		1,2,5,6
	End of life strategies		2,5,6
	Circular Economy		2,5,6,8
	Eco-design		2,5,6
	Repairability		2,5,6
	Consumer behaviour		1,2,4,5,6,8
	Obsolescence		1,2,4,5,6,8
DO	KPI of sustainability during the product lifecycle	Lectures and group activities, design workshops and presentations	5,6,7,8
	Management of sustainability in engineering design projects		6,7,8
	Ethics of persuasive design		1,2,5,6,7

3.2 Implementation approach BY STUDENTS

Once students fulfil the different levels of the pedagogical model, the next step is to generate awareness about how persuasion can be involved in product design for others. For this approach, seven persuasion elements are proposed to be included across the product design process to influence the behaviour of final users.

The seven persuasion elements proposed in this section were selected based on product design approaches related to sustainability and lifecycle [5], emotional product attachment [6], and product lifetime extension practices [7], which are useful strategies to battle product obsolescence, rapid product replacement, and unsustainable consumption patterns. However, the success of the persuasive design, also largely depends on the self-consciousness about sustainability issues, cultural background, and consumption behaviour of the user of the product.

Figure 2 maps the persuasion elements to the product design steps and the persuasion principles from Table 1.

3.3 Assessment of persuasion effectiveness

Since the proposed pedagogical model can be applied to both ON STUDENTS and BY STUDENTS, it is necessary to formulate a proper set of assessment activities to evaluate the effectiveness of the persuasive design approach to students and others after implementing the model. Table 4 summarizes the main structure of assessment activities for students and others.

Persuasion elements	Def of requirements	Conceptual Design	Basic Design	Detailed Design	Persuasion Principles Involved
Personalization / Exclusiveness	✓	✓	✓		6,7
Product simplification	✓	✓	✓		9
Open Architecture of Products	✓	✓			6,7
Materials with low environ. impact	✓	✓	✓		5,6,7
Lifetime Extension	✓	✓	✓		7,9
Measurement and display of environmental impact during the lifecycle				✓	2,3,4,5
Display of all persuasion elements				✓	1,2,3,5

Figure 2. Persuasive elements to be included in product designs by students

Table 4. Assessment activities recommended for the proposed approaches

Approach	Assessment activities	Performance Indicators
ON STUDENTS (Subject: students)	• Surveys about sustainability awareness (Likert Scale) • Presentation of design projects assessed by rubrics. • Co-evaluation, self-evaluation	% of change (Likert scale) Position change of sustainability aspects in the hierarchy of product attributes
BY STUDENTS (Subject: others)	• Surveys about sustainability awareness (Likert Scale) • Surveys about purchasing motivation.	Specific rate of Y/N responses (i.e., Would you buy this product or not?)

4 ETHICAL CONSIDERATIONS

Persuasive design influences people’s behaviour by incorporating psychological techniques in the design process. While persuasive design can be used for positive purposes, such as encouraging healthy habits or sustainable behaviour’s, it can also be used for manipulative or harmful purposes, such as exploiting users’ vulnerabilities or promoting addictive behaviours [5]. As such, it is essential for engineering students to be aware of and consider the ethical implications of their design choices and to use persuasive design ethically and responsibly. The main ethical implications of persuasive design are mentioned as follows:

- Deception and Manipulation: users cannot be aware that they are being manipulated through persuasion, even using misleading or false information.
- The exploitation of Vulnerabilities: persuasive design can take advantage of people’s vulnerabilities, fears, desires, and insecurities to persuade them to take specific actions. This negative reinforcement can lead to anxiety and depression.
- Privacy Interests: persuasion facilitates the collection and use of personal information (i.e., purchasing history, social media activity, location, among others) to create more effective persuasive tactics. This situation enables privacy concerns, especially when users are unaware of how their personal information is used.
- Harmful Behaviour: through persuasion is possible to promote addictive behaviours, such as excessive shopping, use of social media, gambling, or consuming food products. This leads to mid and long-term negative consequences, such as addiction, financial problems, and mental health issues.
- Accountability and Responsibility: persuasive design raises questions of responsibility and accountability, particularly when the design is used for harmful or unethical purposes. Future

product designers using persuasive design will be responsible for being transparent about their practices and ensuring that they are not causing harm to individuals and society.

5 CONCLUSIONS

This article presents a pedagogical framework to incorporate persuasive design in the engineering curriculum. The framework is based on the FEEL-THINK-DO that follows a progressive learning journey through Bloom's taxonomy. The pedagogical model has two main components. In the first one, students learn about persuasion principles and how they relate to engineering topics. In the second part, students identify the persuasion elements and how they relate to the design process and the persuasion principles. The idea is that students navigate from a personal learning experience about engineering and persuasion principles to a discipline-specific application of persuasive design. Since design impacts users' behaviour, it is imperative to educate students about the ethical implications of this design approach. Therefore, responsible, and ethical use of persuasive design must be part of the educational plan. The proposed framework will be implemented through the development of learning modules. The authors are socializing the framework with different stakeholders before moving to the implementation process.

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TAKING THE PULSE OF RESPONSIBLE DESIGN; EXHIBITIONS AS A CRITICAL DISCOURSE VENUE

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ABSTRACT
While there are examples of public discourse around responsible innovation in science, technology, and engineering, less exists on public discussion in the field of responsible design. Without creating space for this to happen, how can design educators stay abreast of the contemporary perspectives of the societies they wish their students to serve?
Using a single case study methodology, we describe a snapshot safari activity which convened a multidisciplinary group of scholars and practitioners to reflect on and discuss design exhibits and their relation to social innovation. We propose this activity as a conceptual model for convening new forms of publics around exhibited work, enabling critical discourse on different responsible design perspectives. We believe this model could form the basis of further active research ultimately supporting universities to stay contemporary in their relationship with society through a better understanding how others understand responsible design and helping design pedagogy nurture the responsible designers the modern world needs.

Keywords: Design show, exhibitions, publics, responsible design

1 INTRODUCTION
This position paper suggests that to teach responsible design effectively it is critical for universities to stay current with how this is understood from different contexts, scales, and perspectives, through dialogue with diverse groups of people. We propose that the creation of new forms of publics could provide an opportunity for vital multidisciplinary discourse and this paper offers one model for achieving this around exhibition materials. A review of literature situates this research within the context of responsible design, and we explore how designers currently engage with diverse groups to understand modern societal perspectives.
We highlight how an activity around a degree show created a vibrant space for discourse on social innovation. Based on this we outline a conceptual model which we speculate could be used to reconceptualise how we might use exhibitions in the future. We propose that using this model, exhibitions could become spaces to convene new forms of publics, enabling critical discourse on responsible design through specific and relevant lenses. We believe this type of discourse is essential in enabling responsible design pedagogy to stay relevant, and meaningful. The study contributes a means of achieving this vital discourse through the proposed model. This qualitative, participatory case study draws on auto-ethnographic reflections on the experience of a snapshot safari activity (described further in the companion paper to this work [1]) without being underpinned by a previously constructed hypothesis. Future data gathering will allow for further inductive theory building.

2 BACKGROUNDS
The European Commission highlight the importance of "engagement of all societal actors; researchers, industry, policymakers and civil society" [2] in the research and innovation process. The practice of design-led responsible innovation generally takes this wide perspective, engaging with society broadly in assessing the potential implications of new technological or scientific proposals and Stilgoe et al., [3] propose four dimensions to support good practice in doing this; anticipation, reflexivity, inclusion, and responsiveness.

In their 2020 report the Design Council reflect on the need for responsible designers, stating: “Rather than a focus on individual user needs, we need to make sure we’re thinking about wider societal and environmental needs” [4]. Responsible design practice, however, often focusses more narrowly on the needs and values of specific communities and user groups, engaging with these limited stakeholders throughout the design process [5]. In his call for a new social agenda for designers, Papanek, described responsible design as “Design for people’s needs not for their wants” [6]. Salamanca et al., go on to suggest that responsible design is “Intentional action that deals with the design, reification, and maintenance of positive, equitable, and meaningful futures desired by sustainable networks of human and non-human actors” [7]. We find ourselves asking; how well we understand the needs of others, and particularly within a design school how are we engaging more widely with diverse groups of people as hybrid communities [8]? In what ways are we convening new forms of publics in spaces of shared reflexivity and learning to challenge hegemonic and dominant narratives? How might engaging in these spaces help new designers improve their sensitivity to current societal values and perspectives, allowing them to contribute to a more ‘social model’ of design [9]?

In their exploration of different forms of public dialogue Chilvers, [10] notes the increasing importance of informal, bottom-up types of participation in invited spaces of micro-engagement. Our case study describes a space where individuals were invited into a loosely structured space to share their personal perspectives around a specific theme of interest in a new form of publics. Warner, [11] describes publics as a temporary and self-organised groups of strangers bounded by an event or shared space and through reflexivity and discourse. Agonistic spaces that facilitate feedback have been used for some time in participatory design, sometimes described as design events [12] or design devices [13] they have involved design objects as probes or triggers to elicit critical responses on the feasibility or desirability of a domain. Dunne, [14] explains how speculative design exhibits created by Royal College of Art students in response to ‘what if’ scenarios are used to inspire, raise awareness, and provoke debate. However, the creation of design events around already curated exhibitions for exploratory discourse on responsible design is not widely discussed and this paper responds to this gap.

3 POSITIONS

Design educators are known to include stakeholders and users in the design process on specific projects, during research phases, co-creation, and participatory design and in the testing and critique of products and services. These engagements tend to include carefully selected groups, those who it is anticipated may be impacted by the interventions being designed. The authors suggest there are opportunities to engage with people in new forms of publics around a broader scope, outside of individual design projects to understand the contexts in which future projects might sit. We propose that even short micro-engagements as participatory design events could enable design educators to hear diverse perspectives which might begin to dismantle dominant narratives, build a more-rounded understanding of responsible design, and gather contemporary insights on how design is interpreted and shaped by society. New models of public discourse like this, leveraging the final degree show, could provide a forum to convene these publics.

4 RESEARCH ENVIRONMENT

In summer 2022 a UK university design school hosted a conference around ‘Design for Social Innovation’. The event (designed and hosted by the Authors), brought together nine visiting academics holding teaching and research roles in different disciplines, connected through membership of a European research network, nineteen local academics, many belonging to the university’s responsible design practice research group, and eleven practitioners from organisations including charities, social enterprises, small businesses and independent consultants working on projects to further social justice, all with existing links to the university (Table 1). Delegates fell into three of the four main roles frequently found in sustainable public dialogue forums [10]; those studying, coordinating, and practicing.

Table 1. Participants

<table>
<tr><td rowspan="2">Visiting Academics</td><td>Disciplines</td><td>Countries</td></tr>
<tr><td>Economics & Management, Economic & Natural Resources, Environmental Education, Governance Law & Society, Industrial Design, Marketing, Organisational Culture, Social Enterprise.</td><td>Azerbaijan, Bulgaria, Czech Republic, Estonia, Israel, Malta, Poland, Romania</td></tr>
<tr><td rowspan="2">Local Academics</td><td>Disciplines</td><td>Positions</td></tr>
<tr><td>Developmental Psychology, Design, Innovation & Global Development, Design Innovation & transnational education, Design & Social Innovation, Fashion Communication & Research Design, Fashion Design, Human Computer Interaction, Interdisciplinary technology, Multidisciplinary Innovation, Fashion Design, Industrial Design</td><td>3 Post-Graduate Students
3 Doctoral Students
10 Teaching/Research Academics
3 Researchers</td></tr>
<tr><td rowspan="2">Local Practitioners</td><td colspan="2">Position and Sector or Organisation</td></tr>
<tr><td colspan="2">Director of Social Design Agency, Independent Researcher, Evaluator, Advisor & Facilitator, Independent Consultant (Third and Not-for-Profit sector), Chief Executive of Regional Charity, Director of a Mental Health & Performance Coaching Organisation, Research Consultant, Managing Director of Social Enterprise School, Manager of Charity and Arts Venue, Social Innovator, Director of Opportunities for a National Charity</td></tr>
</table>

The two-day conference included talks, workshops, 'walkshops' and a snapshot safari activity, designed to provide different spaces for people to share and discuss their experience of and ideas around design for social innovation.

5 CASE STUDY

The snapshot safari activity was designed to provide a space for multidisciplinary discourse on social innovation. It took place around the 2022 final degree show [15] across the University's faculty of Arts, Design and Social Sciences. The exhibition was described as a celebration of students' creative practice and covered the work of students of Interior Design, 3D Design, Design for Industry, Interaction Design, Graphic Design, Fashion Design, Fashion Design & Marketing, Fashion Communication and Architecture & the Built Environment. Provided with a map of the show galleries, participants were asked to work individually for ninety minutes, responding to the following questions, and considering what social innovation meant to them:

- What is the shape and size of design in different social innovation contexts?
- Where and what is designed?
- How has design been used?
- What might have been learned through the design process?
- Might your photo communicate an idea that words cannot?

Through a written brief, people were invited to explore exhibits, taking six photos of things which brought to life their thoughts on social innovation. Local academics accompanied people around the show and helped with queries. Informal conversation between participants took place, sometimes including visiting public, exhibiting students, or teaching staff. After a break, small groups of participants convened for two hours to share and discuss their photos which had by then been printed. People were asked to incorporate their photos into annotated group posters responding to the question "How should we live?". The following morning, posters were displayed, and each group presented their poster which stimulated discussion within the wider group, on different and shared perspectives on design for social innovation.

6 RESEARCH DATA

Data on this case study was collected through Auto-ethnographic observations (as designers of/participants in the activity), an audio transcription of group discussion during the poster exhibition, photos of the safari process and the exhibition posters created.

7 FINDINGS

Participants engaged enthusiastically throughout the individual work and during the small-group and whole-group discussions which were rich and stimulating. People described the experience as pleasurable, enjoyable, and even awesome. While many participants commented on how overwhelming the task felt due to the scale of the design show and the range of exhibits, they felt that the brief helped to set a clear focus. One participant reflected *"Yesterday we had a task. So, my mind was 'listen, I have to choose six photos on a simple criteria', I was automatically skipping those that didn't sync with my filter*".

Participants described being attracted by exhibits with relevance to their own work or interests, and one expressed how the process had made them reflect on their work from a more critical lens as they explored the show. People found it surprising that there were academics and students facilitating the show, not just exhibits on display. Some students were not particularly eloquent or not in a position to explain specific exhibits, whereas others really helped to bring them to life for the participants, this dynamic impacted people's experiences of different parts of the exhibition and the photos they took. The structure of the activity provided different ways for participants to take part, and it was noted that some people engaged more actively in one-to-one conversations, whereas others preferred group discussions. The dialogue evolved as participants moved from considering their individual perspectives to hearing that of others. The posters created by the groups highlighted a range of perspectives on responsible design for social innovation including the importance of ensuring multi-generational discourse and focussing locally for global benefit. Participants asked how we might respond to hidden issues through design, whether discrete design can help to destigmatise and if unfinished designs can help explore possible futures. Summarising the event, a participant said, *"This was interesting, like a mini handbook, of how to actually start a new conversation[...]creating a new space to start new conversation by bringing together actors that wouldn't have come together[...].*

8 LIMITATIONS

This preliminary piece of research considers a single case study, where a diverse group of people already connected through previous collaborations and with shared interests came together to discuss an area of joint concern. Publics convened of people not previously known to each other or from vastly different backgrounds may experience different outcomes. The authors acknowledge that the term diverse has a plurality of definitions and we have a responsibility to consider what communities and narratives need to be included when more consciously convening people. The model proposed in this paper highlights the opportunity for this to be explored and improved through further research.

9 CONCEPTUAL MODEL

Publics are convened through this conceptual model which is composed of and animated through eight connected elements: Place, People, Perspective, Prompts, Process, Pace, Practice and Philosophy. *Place* – The snapshot safari activity can start anywhere materials are being exhibited. An exhibition does not need to be established for the purposes of this activity and any show can be repurposed. *People* – The model can be scaled for use with different sizes of group providing group discussions are appropriately facilitated. Further research might consider including students explaining their exhibits or participating as part of their learning experience. *Perspective* – Participants should be invited to view exhibits from a specific perspective or 'subject of conversation' [13] to stimulate reaction and interaction. *Prompts* – Participants should be provided with questions to set a foundation for the activity and help frame their thinking while exploring the exhibition. These questions should be tailored to the specific perspective of interest. *Process* – The activity should follow the three distinct steps in order. In step 1, people should be given the opportunity to take agency over and understand their own interpretations of the brief through taking photos with the option to discuss with others. In step 2, participants should move on to poster-making and discussion in small groups. Step 3 involves discussing the posters as a whole group. These steps acknowledge and accommodate the spectrum of introversion and extroversion that may exist across a group. The use of photos is a key feature of the model, as having physical evidence early in the process encourages people share their individual perspectives rather than default to groupthink [16]. Different levels of structuring are possible within this aspect of the model. *Pace* – As a micro-engagement the pace and rapidity of the model is important in helping participants focus on the key points and encourage them to summarise their complex thoughts so they can be quickly distilled into poster format. *Practice* – The snapshot safari utilises show exhibits as 'boundary objects' [17] becoming 'tools for conversation' [11] which help gather people for focussed discourse. During this activity the shared space itself becomes a 'design Thing' [18] a socio-material assembly, with participants together shaping an understanding on an aspect of responsible meta-design [19] through their discourse and contributions. *Philosophy* – Designed to create an inclusive, collaborative, and enjoyable learning environment, the activity should have an informal aesthetic with materials written in simple language. It should allow room for creative exploration without setting any expectations on outcomes.

10 PROPOSITIONS

The case study described in this paper demonstrates the potential value of reconceptualised public exhibitions for convening new forms of publics. This paper proposes a model which could be used to convene diverse groups in micro-engagements, around existing boundary objects for critical discourse on aspects of responsible design. Using this model could create space to explore different perspectives on non-dominant narratives such as feminist, anti-ableist, bio-centrist, or post-colonialist practice. Facilitating publics for discourse using this model and incorporating it into pedagogy could enable universities to stay contemporary in their relationship with society and help responsible design teaching stay relevant and meaningful to nurture the future designers the modern world needs.

While this micro-engagement 'takes the pulse' of responsible design, it does not seek to replace the infrastructuring work of long-term stakeholder engagement and attachment forming which are key to enabling deeper discussions on responsible design practice and education. The authors are keen to understand how academics might take the role of orchestrator [10] in these publics, reflecting on what is being shared and using it for greater impact through changes in how responsible design is understood and taught. We believe it would be valuable to carry out further research on how this model might be replicated across exhibitions in other parts of the world, and we are keen to understand what comparative studies might reveal about responsible design in different contexts.

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PEERS AS EXPERTS TO COOPERATE WITH: A CASE STUDY OF TEACHING ACTIVITIES TO SWITCH FROM INTER-GROUP COMPETITION TO COLLABORATION IN A DESIGN STUDIO

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ABSTRACT
Design based learning is a widely and historically rooted approach to design education through which students learn to design by developing projects within the design studio. The physical or digital space of the classroom becomes crucial for students to collaborate in developing their projects with lecturers, technicians, and peers. Group projects often foster peer learning, allowing students to develop high-complexity projects relatively briefly. However, a great emphasis on the team could inhibit the possibility for students to cooperate at the class level. Inter-group knowledge sharing is often seen as a threat rather than an opportunity for improvement. Through a critical action research iteration, this paper investigates the role of instructional design activities and instructors in mitigating competition in a business-like design studio in favour of a more effective inter-group collaboration. The study was conducted in the final design studio of the Design & Engineering Master of Science at Politecnico di Milano and involved 52 students divided into 12 teams. Data was collected through participant observation in class and a final questionnaire at the end of the course. The contribution aims to present the designed instructional activities, provide a hands-on example of possible strategies, and present emerging themes from the qualitative data analysis.

Keywords: Inter-group collaboration, design-based learning, design studio, collaborative learning

1 INTRODUCTION
Addressing global challenges necessitates strong collaboration across cultures and disciplines, intensified partnerships, and consistent knowledge sharing. While competition has historically driven societal development, collaboration is increasingly recognised as crucial for sustainable development, as exemplified by the 17th SDG “Partnership for the Goals”. In this scenario, collaborative learning becomes a strategic asset in formal education curricula. Employing team-based design activities in instructional projects is an effective way to create a collaborative environment where students learn *how to* design (i.e., design specific competencies) and cooperate with others effectively (i.e., transversal competencies). According to Barkley et al., the shift from the traditional to the collaborative classroom should foster a shift also in students’ roles: peers become collaborators instead of competitors [1]. Consequently, peers, self and the community should become an authority and knowledge source beyond the teacher [1]. Previous research in the situated context conducted by the authors showed that team-based instructional projects support these shifts at a team level but might also favour a competitive inter-team environment [2]. Such competition often hinders collaboration and knowledge exchange at a class level. Therefore, teachers should consider the broader context of the class when designing instructional projects, balancing competitive tasks with cooperative tasks to facilitate the exchange of knowledge. Moreover, in school systems where grades are less relevant, students approach projects more casually, leading to self-directed and peer learning. While emphasising evaluation encourages constant commitment, it may discourage risk-taking and knowledge exchange with other teams in the class [2]. Given this contextual observation, the paper aims to present a case study of an instructional design project aimed at reshaping the interactions between teams within a team-based design studio from a highly competitive inter-group climate to a more collaborative one. The shift from objectivism to constructivism in education has led to instructional design focusing on complexity and continuous

improvement [3][4]. The constructivist view holds that learning is a personal process of creating meaning; similarly, instructional design improvement should be based on cycles of reflection and action from which innovation in teaching stems. This approach involves action research, which is a practice-changing practice that helps teachers evaluate their practices and improve their students' learning [5][6][7]. Even if action research is situated and not generalisable [5], understanding how teaching practices evolve through teachers' actions can provide valuable insight into emerging needs and approaches in specific educational contexts [8]. Castoldi [3] identifies three relationships between research and instructional change: i) research on improvements, which provides feedback but does not determine change; ii) research for improvements, which triggers change and is complementary to innovation; and iii) research as an improvement, which reflects and produces a change in professional behaviour and teaching practices and is equivalent to innovation. The latter is most coherent with the action research paradigm and emphasises self-reflective working methods in instructional actions for change. Coherently with all of the above, the present paper aims to present how the change in the instructional design addressed the observed contextual issue of a highly competitive inter-team environment and impacted pursuing the objective of fostering class collaboration on the projects developed in a design studio. Rather than presenting a generalisable solution, the contribution has the goal of disclosing the crucial role of teachers in detecting the inconsistencies of current teaching practices, redesigning coherent instructional projects that guide students to develop sustainable behaviours and attitudes and soundly evaluating these renewed practices.

2 CONTEXTUAL ANALYSES

2.1 The Design and Engineering Master of Science

The Master of Science in Design and Engineering (D&E) is a joint program between the School of Design, Mechanical Engineering, and Materials Engineering at Politecnico di Milano. It trains students in Product Design and Industrial Engineering bachelors to master the design process from concept to manufacturing. D&E courses are mainly in English, attracting international students yearly [9]. Students participate in collaborative design-based learning during the first three semesters of the two-year program. Summative assessments at the end of courses contribute to the graduation score, with design studios weighing more heavily.

2.2 Final project work: the design studio course under investigation

The Final Project Work (FPW) course represents the last design studio of the master's degree. It is the one in which students, divided into project teams, must develop a product of medium complexity by combining the design and engineering skills acquired throughout the master's degree. At the beginning of the studio, teachers propose a general theme to the 52 students in the class. Such a theme is presented in collaboration with a partner company that also provides feedback to the students during the design process and final presentations. Starting from the general theme, teams of four-to-five students develop research and based on that, agree with the teachers on a specific design brief (called counter-brief in the context), which becomes their project area. In the academic year 2022-2023, when the investigation took place, the project's theme was to develop an electric and foldable bicycle in collaboration with a leading Italian bike manufacturing company. The class was composed of 52 students, divided into 12 teams. An interdisciplinary faculty team of six teachers (i.e., three designers and three engineers) and one teaching assistant oversees the project's development throughout the semester. According to their expertise, teachers review the group project approximately every two weeks, providing feedback and suggestions for improvement on the design (e.g., research, concept, functions, aesthetics) and engineering aspects (e.g., material, manufacturing, technical representation). Weekly reviews are moments for formative assessments of students' project development. There are also mid-term and final project presentations when the students receive a summative evaluation (i.e., a mark) from the teachers.

2.3 Observed untoward consequences: poor inter-team climate and cohesion

In the past few years, the researchers, being part of the teaching staff, observed some untoward consequences of the instructional project that became the rationale for redesigning some teaching activities and including a few new ones. Specifically, as mentioned above, it was observed that inter-team collaboration was usually poor, and the competition among teams was very high. Teams of students perceived that their team project was competing with other projects and, therefore, exchanging knowledge with or helping other teams could have damaged one's outcome in terms of evaluation. Students in the situated context appeared to perceive the team as a safe environment to share information and constructive criticism. Still, they struggled to recognise the classroom group as safe to enact these processes. In the last years, several actions have been undertaken and integrated into the course to foster teambuilding and organisation at an intra-team level [10][11][12] especially considering the cultural plurality of teams. However, the inter-team issues have been poorly studied so far. Considering the team effectiveness framework proposed by Tucker [13] and applying them to the class group, two of the 22 factors and associated recommendations for teachers for task design appeared particularly relevant: team climate and team cohesion. In Table 1, the original factors proposed by Tucker for teams are interpreted and adapted considering the class group. The recommended teaching responses (see Tab. 1) have been considered in redesigning the instructional project.

Table 1. Two poor factors in the class group. Adapted from Tucker [13, pp. 14–15]

Factor	**Description**	**Recommended teaching responses/strategies**
Team climate	It determines how freely teammates can share opinions and ideas.	Communicate with students to promote a team climate of inclusiveness, freedom, interpersonal trust and respect.
Team cohesion	It is the tendency for a group to stay united in pursuing its goal and objectives.	Foster positive interdependence between individuals and teams by promoting student-led reciprocal teaching.

3 METHODS

3.1 Action research: instructional activities to foster inter-group collaboration

First, throughout the course, the teaching staff repeatedly made explicit the following metaphor to underline such expected team attitude toward the class group: *"Let's imagine that we are a large design studio to which a major client has entrusted the development of a project. We aim to develop many ideas and turn them into excellent and equally worthy projects"*. This metaphor was used to convey the message that the class shares a common goal, as opposed to the individualistic pursuit of prevailing over the work of others. Coherently with this metaphor, the researchers introduced two sets of activities hinged on fostering inter-group collaboration based on two principles: i) inter-team shared tasks and ii) inter-team help and feedback on projects. These two principles were identified as suitable actions to enhance the class climate toward collaboration.

3.1.1 Inter-team shared tasks: sharing knowledge from the beginning of the design studio

Figure 1. Collaborative board for counter-brief definition and selection

The teams were required to develop two initial tasks collaboratively: the technical research and the counter-brief development and choice. Technical research was proposed at the beginning of the design studio to collect the technical information necessary to develop the design of an electric and foldable bicycle. Instead of asking each team to build its research on all the technical aspects, we assigned a specific topic (e.g., batteries, foldable systems, electric motors). The teaching staff evaluated each delivered research and then shared it with the rest of the class to exchange the retrieved knowledge. In parallel to the technical research, the teams were asked to develop contextual research to diversify the specific counter-brief per each team. Each team developed this process autonomously in the past, often causing overlap between particular design challenges and fostering competition between teams. Given this issue, we proposed the Padlet platform to identify 12 appropriate contextual challenges collaboratively. Specifically, on a shared board with the class, the teams were asked to brainstorm possible contexts to develop the project. Thanks to the teams' contribution, the board grew with different proposals that students clustered autonomously into themes (see Fig. 1). The teaching staff periodically reviewed the board and commented on the various proposals by highlighting challenges and opportunities. During in-class reviews with the team, the teachers were able to orient each team toward developing a specific, appropriate, and promising challenge among the themes emerging from the board organisation.

3.1.2 Inter-team help and feedback on projects: integrating knowledge and competence exchange

Several formal moments in class were organised throughout the course to foster peer help and feedback on projects. Specifically, three types of activities were proposed. First, the teams were asked to write feedback to all the other teams during the two mid-term presentations and the final presentation on a shared online Padlet board (see Fig. 2.a). Then, after the second mid-term presentation, a peer-help activity was organised to foster knowledge exchange on the projects. During the afternoon dedicated to the activity, teams were free to set a series of appointments for a fifteen-minute review with teams they felt could have helped solve their current design issues. The role of the teachers (i.e., the researchers) was to facilitate the peer help session by keeping track of time. Finally, in the final part of the course, several reviews on the design and manufacturing aspects were organised in the form of a simultaneous review of two teams. During the review, the teams and the teacher contributed to spotting criticalities and finding solutions.

3.2 Evaluation of the outcomes: participant observation and final open questionnaire

The activities' impact on inter-team collaboration has been evaluated throughout the course through participant observation of the researchers in the role of teaching staff. Additionally, at the end of the course, students were required to fill in an open questionnaire that included a specific question related to inter-team and intra-team collaboration (see tab. 2, item 3).

Table 2. Questions asked in the open questionnaire

Nr.	Item
1	What have you learned in this course?
2	Compared to other project-based courses, which have been the advantages of the course (if any)?
3	Compared to other team-based courses, which have been the advantages of this course (if any) in terms of iter-team collaboration (i.e., between teams) and intra-team collaboration (i.e., within your own team)?
4	Which was the thing you liked most?
5	Which was the thing you liked less?
6	Any suggestions for next year?

Completing the questionnaire was elective, and 20 students over 52 participated. To qualitatively interpret the results, the researchers adopted an evaluation coding strategy described by Saldana [14]. Indeed, in evaluation coding, the researchers interpret the qualitative commentary provided by participants on a specific programme policy or action [14]. To perform evaluative coding, the research team reviewed the answers by assigning a series of codes related to positive (i.e., using the sign + between parenthesis) or negative comments (i.e., using the – sign between parenthesis) followed by a specific evaluative code. For instance, the following sentence was coded as follows:

Having critical feedback from colleagues was a good thing, and I also liked being able to give advice and feedback to other groups.	CODE (+) inter-team > peer feedback

The codes present two levels. At the highest one, the researcher focused on the aspects related to inter-team dynamics and also included intra-team dynamics to extensively evaluate the student's perception regarding collaborative elements in the class (e.g., (+)/(-)/(=) inter-team or intra-team). Then, sub-codes were developed to interpret the specific aspects emerging from students' answers (e.g., peer feedback).

4 RESULTS AND INTERPRETATION

From the participant observation conducted by the researchers in the teachers' and assistant role throughout the course, it was noted that the students participated in activities related to inter-group collaboration. Also, it was perceived as an overall improved climate of help and support between groups. After collecting and coding the open questionnaire, the data confirmed such observation.

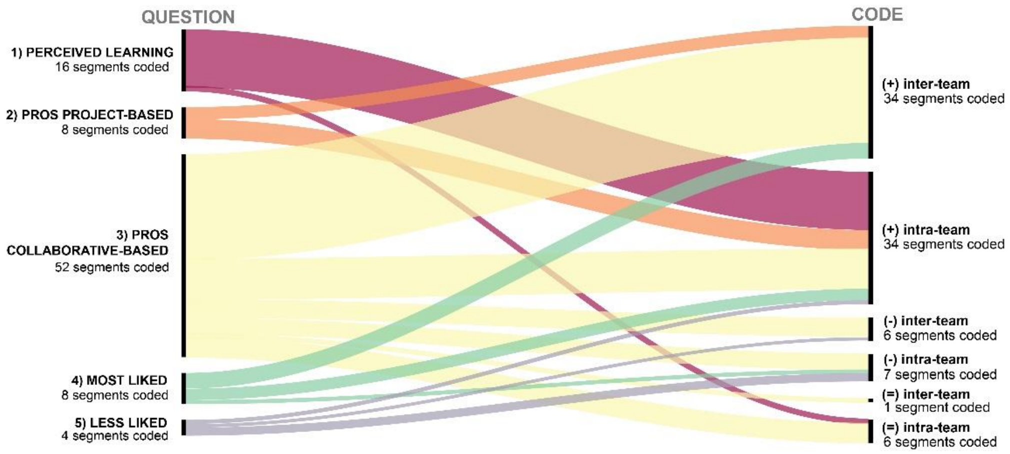

Figure 2. The distribution of the coded segments concerning the questions of the open questionnaire (left) and the higher level of the evaluation coding (right)

Referring to the visualisation proposed in Figure 2, the interpretation of the students' answers through coding showed that text segments that referred to collaborative aspects in the course are in great majority positive (i.e., of the total of 88 coded segments, (+) inter-team counted 34, and (+) intra-team counted 34). Therefore, data showed that students positively perceived the collaborative environment in the course. When asked to compare the FPW course to previous collaborative-based courses, students' answers focused on inter-group collaboration.

Table 3. Subcodes of the high-level code related to inter-team collaboration positive aspects (i.e., (+) inter-team)

Subcodes of the (+) inter-team code	Count
(+) inter-team	34
1. awareness	1
2. collaboration	**7**
3. communication	2
4. culture of help in the class	3
5. knowledge sharing	**10**
6. management of time	1
7. peer feedback	5
8. project	4
9. tasks division	2

Subcodes of the (+) inter-team code	Count
10. teaching activities	3
10.1. sharing reviews	**13**
10.1. 1. feedback during presentations	1
10.1. 2. two-groups review	6
10.1. 3. face-to-face peer help	6
10.2. shared class tasks	**7**
10.2. 1. project briefs	1
10.2. 2. technical research	6
11. togetherness	4

By analysing the most recurrent sub-codes (see the grey row in tab.3), it emerges that the inter-team collaborative environment in the class was positively evaluated and that the class showed an increased openness of teams to share knowledge. Specifically, the proposed teaching activity (i.e., 10) was often explicitly mentioned concerning the positive aspects of inter-group collaboration, showing a correlation between the climate and the proposed activities. Hence, a finding is that the proposed activities fostered an enhanced climate of knowledge sharing and cohesion among teams coherently with the two factors considered from Tacker's [13] framework to design the activities. The inter-team improved dynamics emerge prominently with question nr.3, in which students were explicitly asked to evaluate the advantages of the FPW course compared to previous experiences regarding the collaborative environment. On the other hand, the benefits of intra-team collaboration and its relevance according to students' perceptions emerge more from all the questions, showing its perceived importance for the project's success and the overall design studio experience. Among others, students mentioned only the aspects of collaboration related to intra-team dynamics, not inter-group collaboration. The research team interpreted this result concerning the project's complexity and the short time to develop the design project, elements of the course that make the intra-team organisation a crucial part of completing the work to be done successfully. In students' words, organisational skills are not limited to dividing tasks but also include effective communication and conflict-resolution strategies. Students report that these skills are more critical for the project's success than technical abilities. Although students consider inter-team collaboration one of the most successful aspects of the course, it is not perceived as a learning outcome. One possible interpretation is that students hardly connect inter-team collaboration with relevant learning outcomes of a design studio course, as they are not accustomed to considering it as a crucial design competence. Finally, it is worth mentioning that six negative comments related to inter-group dynamics were coded. Specifically, three students highlighted the fact that not all the teams were equally willing to share information at a class level and committed to the inter-team activities, two students argued that the intra-team activities were less useful in some phases of the design process, and one student mentioned the perception of a competitive environment in between teams.

5 CONCLUSIONS

This paper presented action research in the context of a design studio, where a highly competitive environment creates a barrier to knowledge sharing and cohesion at a class level (i.e., inter-team collaboration). As part of the teaching staff, the researchers redesigned and integrated some new instructional activities to foster cohesion and improve the climate between teams of students developing different projects. The participant observation conducted by the researchers throughout the course and the data collected through a final open questionnaire with students confirmed that the activities fostered an improved climate of help and support between groups. Inter-team collaboration in the course was considered a positive aspect compared to students' previous experiences in collaborative-based courses, confirming that the activities proposed supported this aspect. Therefore, observing an issue in the context (i.e., high competition, poor inter-team collaboration) provided a rationale for changing the instructional design. In the role of teachers, the researchers reconsidered their practices accordingly and more effectively guided students toward sharing knowledge and ideas with other teams.

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TOWARDS A NEW DESIGN OF SUSTAINABLE SOCIAL DEVELOPMENT PROJECTS THROUGH PRECISION AGRICULTURE AND DATA SCIENCE IN THE EDUCATIONAL MODEL TEC21

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ABSTRACT
In the 2025 strategic plan, the mission of Tecnologico de Monterrey is to train people with a humanistic vision and to be internationally competitive in their professional field. During the last 15 years, through the design of social development projects in marginalised areas of the *Sierra Gorda* of Queretaro, which undergraduate students carry out during their university studies, different projects have been implemented in which added value is given. Agricultural products are based on local supply chains for raw materials and the help of the government of Guanajuato and Querétaro to bring these products to the market. Furthermore, through the studies carried out on different seeds and crops in the Experimental Agricultural Field of the Tecnologico de Monterrey, CAETEC has created a new methodology to increase the productivity of these production units and make them the economic engine to eliminate poverty in marginalised areas by applying design techniques, project management, statistics, design of experiments, and data science. The use of precision agriculture at CAETEC has generated valuable information on cultivation methods to improve productivity and information obtained from greenhouses built using the principle of Agritronics that are operated by renewable energy to harvest agricultural products in remote areas and are more marginalised from the country. Students lived a social experience apart from the academic knowledge acquired to design sustainable social development projects presented in this paper.

Keywords: Precision agriculture, data science, design of experiments, higher education, educational innovation

1 INTRODUCTION
The economic crisis of 1994 was the trigger for the development of social projects to generate alternatives to help low-income people have a stable economic life. According to CONEVAL (2020) [3], in Mexico 43.9% of the population is living in poverty, this is equivalent to 55.7 million people, of which 8.5% live in extreme poverty (equivalent to 10.8 million people). Therefore, creating social projects to improve the quality of life for this population percentage is of great importance; that is why the Tecnologico de Monterrey committed to society and began to design activities and projects of agro industries within its programs to help marginalised areas.
As an educational institution, Tecnologico de Monterrey has as its mission to develop in its students the competencies of ethics, citizenship, and payment of the social mortgage; this mission is achieved by designing space where its students put into practice their knowledge for solving real and social problems through activities (Villanueva, 2018) [15]. Week i is an example of this; it is a project where students take part in addressing a specific social issue, developing disciplinary and transversal competencies, with the accompaniment and guidance of faculty and education partners (Tec. de Monterrey, 2017)[14].
Data science (DS) plays a key role for successful collaborations between institutions and partners. DS refers to an interdisciplinary field that involves a series of methods, processes, and systems, with the aim of extracting knowledge from data. It has proved to be of great application in very different areas, particularly in Education (Klašnja-Milićević et al., 2017) [8]. In this project, data science in precision

agriculture allowed the iteration of possible spatial and temporal variations to improve existing agricultural practices (Maohua, 2001) [9].
This document summarises the experiences in the design of databases both in classes with the immersive experience with Centro Agrícola Experimental del Tecnologico de Monterrey (CAETEC) which is a living laboratory focused on the practice of techniques and theory to maximise the experiential learning of students according to the TEC 21 Model of the Tecnologico de Monterrey (challenge-based learning) and the immersive experiences of week i to design and manage social development projects through teams. Through Solidarity Engineering, that is defined as the ability to design and execute social development projects through multidisciplinary groups based on simple and engineering solutions (Acuña *et al.*,2017) [1], together with a group of teachers and students, an activity called "The Solidarity Route of *Sierra Gorda*" was implemented. The objective was to identify spaces in which students apply their knowledge with a positive impact generating a "win-win" relationship with the community.

2 DEVELOPMENTS

The main purpose of the Solidarity Route is to achieve poverty reduction through social development projects. Hence, Week i looked the design of community interventions that were based on merging the culture and customs of each community with Solidarity Engineering, DS, and technology of the institution. It also was looking for designing solutions to their daily problems, contributing to the reduction of poverty in these areas through productive designs (González, 2018) [6]. This activity also was designed to sensitise students about poverty and the needs of the poorest.

2.1 Methodology for social projects

First, it was important to design the Solidarity Route activity based on a humanistic vision with the philosophy of Solidarity Engineering. The Solidarity Route of the *Sierra Gorda* was designed to have a duration of 5 days. The activity was supported by a team of professors from different specialties of the Tecnologico de Monterrey Campus Querétaro, civil society organisations, government entities at municipal, state, and federal levels, and the beneficiary community, and of course the students. This activity was carried out in neighbourhoods with a high rate of marginalisation and poverty located in the city of Guanajuato and Querétaro.
The project was organised in three stages: diagnosis, theorising, and validation. The diagnosis was centred first in the definition problem. The civil society, municipality, and community together with the teachers of the Tecnologico de Monterrey discussed the main problems and needs of the communities. Only one community was impacted per activity. Design thinking was the cornerstone for the design of the activity of this stage to define the objectives that must be achieved in week i. The Systemic design was used to co-create the definition of the intervention of internal and external actors of the project.
In the theorising part, the formalisation of the diagnosis must be done; in this stage is where the definition of all the actors, sponsors, deliverables, procedures, problems, activities, and the design of all the possible solutions are done. For the validation phase techniques of Design thinking such as brainstorming, mind maps, among others were used to abstract the definition of the problem and to generate all the activities. It is at this stage where the calendar of the activity is proposed as well as the commitments acquired for all the actors involved in this project.

2.2 Social development projects as a source of data

There were other factors that had to be considered for the implementation of the Solidarity Route activity. Although the main purpose of this activity was to help the poorest communities, there was a wonderful opportunity to get data from the communities that can be analysed and tested in the CAETEC as a means to improve future projects into the communities. For example, greenhouses and backyard gardens installed must have a slogan that the beneficiaries must register the information to continue feeding the databases.
Once the database was gathered, then it was possible to integrate and improve the harvest with the help of precision agriculture that is defined as: "A management strategy that gathers, processes, and analyses temporal, spatial, and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production" [7].

Together with institutions as SADER and INEGI, it was possible to obtain sensitive information regarding the Bajío region to build the databases. The collection of data of important variables as: Soil characteristics, Crop potential, Active components of the crops, Hydrography, Carbon footprint, and climate impact is needed to implement the designed projects. The information provided by CONEVAL was used to select the municipalities with the highest level of poverty. The microclimates at *Sierra Gorda* allow the sowing and exploitation of different agricultural products. It is worth noting that it was necessary to know in advance an overlook of the crops and roots that naturally occur and the possibility that those crops and roots can grow there, this allowed to determine if the designing of a project was going to succeed.

2.3 The effect generated by the development of social projects

Once that the three initial parts are solved, then it is possible to determine the needs for the communities, for instance the construction of greenhouses, backyard gardens, rehabilitation or renovation of buildings or sport courts, seek solutions for the overproduction or lack of production of some fruit or nuts, among other necessities. The team of the activity was confirmed by one teacher and students belonging to bachelor's degrees in marketing, or several areas of Engineering such as industrial, mechanics, mechatronics, food chemistry, biotechnology, civil, and agronomy.

In 2016, week i was implemented in one of the poorest towns in Mexico, Victoria-Guanajuato; and it was analysed that for greenhouses installation the possibility of the implementation of Agritronic sensors which work with renewable energy. Nevertheless, the greenhouses were installed, and the community was trained to maintain, operate and collect the produced data. Several backyard gardens were implemented with the commitment to inform any incident and the quality of the crops. Figure 1. Projects such as elaboration of nectars, fruit paste, sweets from the region, were implemented as well. The machinery for peeling some nuts, parts of some machinery or other kind of help to the community was also implemented.

Figure 1. Backyard gardens in Week i 2016 at Victoria, Gto. (Own source)

In 2017, week i was implemented in the same municipality but in a different region. For that occasion, several fruits were used to produce jams or fruit paste. The main idea was to generate products with added value. Again, the implementation of greenhouses and backyard were done with the agreement of collection of data and to inform any incident during the documentation and to make a statistical treatment of the project (González, et al., 2018)[4]. Figure 2.

Figure 2. Production of jams in Week i 2017 at Victoria, Gto. (Own source)

For the week i of 2018, the Solidarity Route worked in the municipality of San Luis de la Paz in the community of Rancho de Guadalupe of Guanajuato. In this region, the inhabitants had already greenhouses built in the 70´s, therefore the project objective was to reactivate their greenhouses, with new roofs and a modern way of irrigation, additionally, backyard gardens were also constructed. In this community there was a greater need to improve their agro-industrial approaches (cheese and yoghurt factories). Thus, the objective for the teams was the rehabilitation of the agro-industry area, as well as the establishment of a children's sports centre and the restoration of the community's chapel that had structural damage (Cáceres, 2018) [2]. Figure 3.

Figure 3. Rehabilitation of the greenhouses in Week i 2018 at San Luis de la Paz, Gto. (Own source)

For the week i of 2019, the Solidarity Route worked with *La Estacada* and *Tzibantza* in the State of Queretaro, the activity consisted in the designing and building family gardens, greenhouses, and ovens for bread; give courses to the inhabitants about food processing; design and implement a steamboat's festival illuminated by paper balloons, to celebrate the day of the dead for tourist attraction. During the pandemic, week i was suspended, this caused several problems in the collection of the data. It was when the CAETEC entered the project to help with data collection. CAETEC already had greenhouses and irrigation systems, a cattle herd focused on milk production, drones and sensors to collect information, and some many different projects that could help to improve the life of the poorest farmers. Based on the information provided by CAETEC and with the use of mathematical models, it was possible to find the best food blends of cows based on the nutritional values prioritising the cost for the optimisation of farmers' economic resources and looked for the best combination of nutrients of the cows (Saavedra et al, 2022) [11]. Together with the information obtained from the greenhouses and backyards, CAETEC and the communities it was possible to improve the development of agricultural products, and furthermore, impact the poorest people to improve their harvest.

3 RESULTS

With the implementation of the social development projects carried out in *Sierra Gorda*, several goals were achieved. The most important was that the activity contributed to help the poorest communities in several areas by improving the condition of the community according to their needs. AgroProject databases were used to collect the data. All the characteristics were collected by region, this provided, and it will continue providing, important information that permits going back to the communities in the next years with new projects and proposals of agro-industrial areas. In this database, characteristics of the crops and the areas of high productivity in the *Sierra Gorda* were entered. It was possible to test and contrast with the active substances; a suggestion for sowing a product is added with a mathematical model.

The second goal achieved was the possibility of collecting data for each region as the characteristics of the region. The variables of interest were types of farms, climate, orography, hydrography, and impact on biodiversity. The information collected in the *Sierra Gorda* activity together with Precision agriculture and DS made it possible to experiment with new techniques for sowing different products that can be replicated in agro-industrial projects, to improve quality and richness of nutrients. One example of this practice was the results obtained with the *chilcuague*, which has been used for many years as a bactericide and can treat toothache, the aim of the research was to evaluate if the *chilcuague* that grows wild has the same characteristics as the *chilcuague* reproduced in farmland, and if the *chilcuague* has the same characteristics in the three geographical regions (Atarjea, Xichú, and Victoria). The two-factor factorial design is the statistical technique that can be used to validate this kind of experiment. For this model each replicate of the experiment contains all treatment combinations and it is necessary to have at least two replicates of the treatments. The order in which the observations are going to be taken will be at random so that this design will be a completely randomised design. All the factors are assumed to be fixed. The treatment effects are defined as deviations from the overall mean and the effects of the interactions are fixed and add up to zero (Montgomery, 2011) [10].

The effect model i was given by:

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \epsilon_{ijk} \qquad (1)$$

where:

□ is an overall mean effect,
τ_i is the effect of the ith level of the row factor A,
β_j is the effect of the jth level of column factor B,
$(\tau\beta)_{ij}$ is the effect of the interaction between i and j
ϵ_{ijk} is the random error, Normal(0,□^{2})

For the experiment, ten plants were taken from wild areas and ten were grown in farmland (Factor A) in the three different geographical areas (Factor B: Atarjea, Xichú, and Victoria). For this kind of design there are three hypotheses to be tested:

- The means of the amount of active component (affinin) of the chilcuague in the three geographical areas are the same.
- The mean of the amount of active component (affinin) of the chilcuague in farmland is equal to the mean of the amount of active component of the chilcuague that grows wild.
- The mean of the amount of active component of interaction between geographical area and sowing type (affinin) of the chilcuague in farmland is the same.

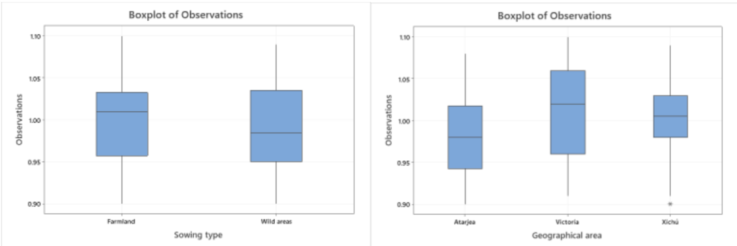

Figure 4. Boxplots of the amount of active component (affinin) of the chilcuague of Sowing type and Geographical area (Own source)

The analysis of the data was done with Minitab 19 Software. As it can be seen in Figure 4 the behaviour of the two factors is pretty similar among the categories. In order to probe that, an ANOVA was computed, (Table 1) and it was found that the geographical area, the sowing type, and the interaction are not significant at 95% of confidence level with p-values of 0.2484, 0.6052, and 0.1044, respectively. In other words, there is no difference in the amount of active component (affinin) between geographical areas, sowing types, and their interaction.

Table 1. ANOVA Table for two-factor factorial design

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Geographical area	2	0.0085	0.0043	1.4293	0.2484
Sowing type	1	0.0008	0.0008	0.2703	0.6052
Geographical area*Sowing type	2	0.0141	0.0070	2.3564	0.1044
Error	54	0.1611	0.0030		
Total	59	0.1845			

4 CONCLUSIONS

The results presented in this document are important not only for the communities where a lot of people from the poorest regions were benefited, but also for all the actors involved in the social projects. Soft methodologies were used to define activities and attitude for week i based on 4 types of thinking: concurrent, systemic, prospective, and resilient. Moreover, the students lived a social experience apart from the academic knowledge acquired, it was found in the final comments of students that the involvement of the project helped them empower themselves and the community additionally they also mentioned that it was an enriching experience where the improvement of local products induced positive changes in the working lifestyle of the inhabitants, leading them to have a better life. It has been proved that there is no difference between the locations nor in the type of sowing. This opens opportunities for sowing more types of products in different areas. The implementation of data science in development projects with precision agriculture can be a key part in ethical decision-making and a tool for resource optimisation. The gaps of inequality in the communities could be shortened by strengthening local economies. But more importantly, these projects are highly replicable, and have the characteristics of being a long-term benefit led by the communities that decide to adopt them.

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READING, WRITING, ARITHMETIC… ROUNDNESS? PREPARING YOUNGER LEARNERS WITH FOUNDATIONAL CIRCULAR ECONOMY EDUCATION TO ALLOW FOR A CIRCULAR ECONOMY ACCELERATION AT HIGHER EDUCATION

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ABSTRACT
Education is a moving practice. As new theories, practices, technologies and evidence emerges, all educators have a responsibility to ensure their teaching is at the forefront of their subject and specialism. The traditional 'reading, writing and arithmetic' of old has been replaced with a much wider suite of skills, but as our world changes with the climate crisis and the rise of eco-anxiety, there are new learning paradigms that are essential to the growing learner and engaged human. The circular economy is one such element. A system that aims to keep materials and resources in constant flow, whilst also creating a regenerative future is arguably a critical system to be understood – and practiced in a variety of ways – by even the youngest of learners as a foundational education subject.
This paper covers a case study for a new education paradigm that is believed to be the first of its nature in the UK - working with a local authority to develop an online city-wide circular economy module that all Key Stages could engage with, along with a reflection on how circularity is currently taught and displayed on a UK BSc/BA Product Design course. By looking at how circularity can be embedded at earlier Key Stages as a core skill, the aim is to discuss how higher education can then push the progression and practice of circularity in each specialism and help the acceleration towards a regenerative future. How might our courses change if we were working with more prepared students?

Keywords: Circular economy, pedagogy, education, climate education, climate crisis, eco-anxiety, product design

1 INTRODUCTION

1.1 What actually is a circular economy?
A Circular Economy (CE) seeks to create a closed-loop system of materials and resources, through a variety of business models and practices ranging from Reuse to Refurbishment, Repair and Regeneration (and many more), encompassing practices from government and industry to those of an individual. However, the term 'CE' does not have any clear or singular origin – rather it has been defined and refined over many years from the 1960's by contributors such as Prof. John Lyle; architect and author of 'Cradle to Cradle: Remaking the way we make things' William McDonough; his co-author, chemist Michael Braungart and the architect and economist, Walter Stahel. The principles covered in Rachel Carson's 1962 book 'Silent Spring' have also contributed to the CE principles, as have the three Rs of Reduce, Reuse, Recycle, [1] which came about some time in the 1970's, after the first Earth Day in the USA. [2] However, although the CE encompasses many different, overlapping practices and has been growing particularly in industry and international policy over the last 20 years, the actual terminology is yet to break into everyday language, rather being confined to said policy and industry. The more simplistic 'three R's' are used in common language, or often just 'sustainability' – a nuanced term that has no clear definition as it can relate to, be argued and understood in myriad ways, as discussed by Ramsey in 2015 [3]. This lack of singular definition for the CE is problematic, as whilst each of the elements can be understood alone, such as pure materials, reduction of material use and consumption, reuse, repair, recycling (and include the three R's themselves) and much more, having an understanding

of how all elements combine and interrelate with one another in a functioning CE allows for a deeper understanding not only of the practice, but how they can be actioned on an individual and local level, (as well as within business, local/national government and international collaboration). But whilst the individual is critical to the success and implementation of the CE through behaviour change, there is a deepening concern that the pressures of doing the 'right' thing weighs disproportionately on the younger generations.

1.2 From Eco-Anxiety to Empowerment

The term 'eco-anxiety' is relatively new, and whilst it is not yet deemed to be a diagnosable condition, public health experts have been reporting an increase in both adults and children presenting with increasing levels of 'a chronic fear of environmental doom'. [4] Mala Rao and Richard Powell of Imperial College London's Department of Primary Care and Public Health wrote in a 2021 British Medical Journal Opinion piece of how eco-anxiety 'risks exacerbating health and social inequalities between those more or less vulnerable to these psychological impacts.' Rao and Powell also noted how eco-anxiety had a 'disproportionate' impact on children and young adults – pointing to a 2020 survey of child psychiatrists in England which showed that 57% were seeing children and young adults who were notably distressed about the state of the environment and the global climate crisis. [5] The closing call of Rao and Powell was to global leaders – to 'recognise the challenges ahead, the need to act now, and the commitment necessary to create a path to a happier and healthier future, leaving no one behind'. Another study from the University of Bath in 2021 looked further afield – surveying 10,000 young people aged 16-25 in 10 countries about climate change (UK, USA, Australia, Brazil, Finland, France, India, Nigeria, the Philippines and Portugal). [6] Overall, 75% of respondents said, 'the future is frightening' and more than 50% of respondents saying they felt 'sad, anxious, angry, powerless, helpless and guilty' about the climate crisis.

This trend can also be seen in a more local level. In the early survey results of the 2022 'A-Round: Brighton & Hove' project, from 8 different schools across the city ranging from infants to college level, in both public and private schools, all reported seeing eco-anxiety in their students. This was not particularly surprising for the older students who may be more exposed to the 'Greta Thunberg Effect' [7] but seeing eco-anxiety manifesting in younger students was concerning for the team undertaking the project. [8]

1.2.1 Moving to Empowerment

From the studies above, and by the evidence presented by the school respondents in the city of Brighton & Hove, eco-anxiety can now be seen in young people of all ages, across the world. Whilst some locations are more likely to see the immediate first-hand implications of the climate crisis, the digital connectedness of our world and our younger digital natives ensures that wherever they call 'home', our youth are feeling the burden and uncertainty of what the future may bring. [9] However, in their opinion piece, Rao and Powell also offered suggestions to alleviate the rising levels of eco-anxiety – including 'access to the best and most reliable information', 'how to connect more strongly with nature, contribute to greener choices at an individual level and join forces with like-minded communities and groups'. [4] .Equipping our young with clear, scientifically founded, globally minded as well as locally actioned knowledge and practices could not only help to alleviate eco-anxiety, but also raise generations with a fully embedded set of 'circular skills' that are as familiar as reading, writing and arithmetic. What if circularity and everything that the practice entails was just part of what our students *did*? This paper proposes possibilities, using the case study of the Interreg funded BLUEPRINT to a circular economy Work Package 3 school project 'A-Round: Brighton & Hove' completed in the city of Brighton & Hove in 2022, plus reflections through the lens of a current presentation of a UK-based BSc/BA Product Design course.

2 THE A-ROUND: BRIGHTON & HOVE CIRCULAR SCHOOLS PILOT PROJECT

Formulated as a continuation and development of an earlier BLUEPRINT work package which saw experts visiting schools to conduct short workshops on composting / food waste / clothing and textiles / single-use plastic and packaging / technology and WEEE (Circular Schools, Brighton and Hove led by Sussex Wildlife Trust, 2021), the A-Round: Brighton & Hove circular schools project (ARB&H) sought to explore how CE education could be embedded in as many schools as possible across the city. Given

the restrictions on available expert time, school availability, school staffing levels and ever-changing CV-19 restrictions, 'in-person' sessions had many limitations, thus it was decided that an online resource would instead form the basis of the Phase 2 project (ARB&H). An online resource also had the advantage of being more flexible for schools to fit extra learning into the school week, allowed for accumulative knowledge over a period of weeks, allowed for sessions to be used by as many schools as possible simultaneously– and also allowed resources to be re-run whenever needed – with the same, or different students. Schools across the city were surveyed to understand what elements of circularity were already taught (if any), what students were most concerned about, and what gaps needed to be filled.
Although the responses were small (10 schools ranging from infants to college levels), there were very clear areas that ARB&H could tackle. Climate change, pollution and plastics scored highly on the concern list from students, along with food growing and food waste. Time was listed as being the main reason why schools were unable to embed more CE learning into their week, as well as an unease that teachers 'were not expert enough to provide the right information' [8]. Other elements requested by schools included opportunities for practical (away from the desk / screen) learning, and for activities that could foster collaboration – both areas that were also recommended by Rao and Powell in their study as possible areas to allow the alleviation of eco-anxiety. Phase 1 had also identified the need for city-connection to allow students to understand the real context of subjects being taught in their local environment and this was backed up in the early survey responses – schools wanted the ability to link learning with the city itself.

2.1 Designing A-Round: Brighton & Hove

Working with the 'wish list' from the schools and the learnings from Phase 1, ARB&H was created as a 10-week pilot and published using the online education platform 'Thinkific'. Each main subject of Plastic / Food / Stuff / Climate was covered over a period of 2 weeks, with an introduction to the CE in week one, and a Wrap up in week 10. Each week featured:

- A short (3-5min) introduction video to each subject (intro to the CE/Plastic/Food/Stuff/Climate)
- Downloadable teacher resources and lesson plans
- Local 'circular hero' videos (specially commissioned 3min interviews with business owners/project creators in Brighton & Hove who are showing CE in practice)
- Presentations to use in class (in three different levels of complexity/knowledge for each subject – allowing the teacher to select the correct level for the class based on experience or age)
- Circular School Challenges (where collaborative, whole school activities such as food waste audits, plastic audits, or setting up a swap shop were encouraged)
- Circular Champion Pledges (10 personal pledges for students to take, based on positive behaviour change e.g., visiting a refill shop, buying something second-hand, repairing an item at home)
- Discussion Data (where students were surveyed on pledges and behaviour changes each week)

There was also an online Google Map, with business tagged across the city related to each of the four main subjects (Plastic/Food/Stuff/Climate) to be used for discussion in class and a 'Circular Champion Trail Map Challenge' which saw the creation of a physical trail across the city to specially selected locations / businesses working within a CE, to collect a letter of the alphabet, to create a missing 10 letter word. Locations included refill stores to food waste café's, a 'charity superstore', a wood recycling project and a community bike repair scheme, students were encouraged to explore the city they live in with new eyes. With a very rich and varied set of resources, the ARB&H project aimed to create a testbed for ways to educate school to college level students about the complexities of the CE in action and is believed to be the first such multi-Key Stage online course in the UK to be available to schools for free.

2.2 A-Round: Brighton & Hove – running the pilot

Due to the timings for the end of the BLUEPRINT project in March 2023, the ARB&H project actively ran across the city in the Autumn term of 2022, from the end of September to early December. In total, 8 schools signed up to the pilot – 1 school ran all content as designed with 60 Key Stage 2 students, 1 school used some content with 20 Key Stage 5 students with advanced educational support needs (whilst also running the behaviour change pledges with their staff) and the remaining schools communicated that they planned to use the resources in their pre-planned sessions and themed weeks in Spring/Summer 2023.

2.2.1 Results
Data was collected weekly from students during the 'Discussion Data' sessions – polling them with set questions using a 'hands-up in class' method to determine knowledge changes, changes in behaviour and also attitudes and opinions. Some behaviours were found to be already embedded in their lives (such as carrying a reusable bottle or buying something second-hand), however many aspects of learning were new - the fact that plastic came from fossil fuels, or what the food waste pyramid was (and what it meant for climate). Perhaps the most important data came from the changes in attitude – at the end of each subject covered (Plastic, Food, Stuff, Climate), 100% of students felt that they could create some positive change in that subject area – a general increase of between 15-22% in positivity from week 1 of the subject, which translated to a lowering of eco-anxiety around the subject – the students felt they *could* enact change.

Also, on finishing the course, 100% of students surveyed stated that they understood the elements of the circular economy and how it related to the city of Brighton & Hove (this was also backed up by the teachers, who stated their excitement and surprise when their KS2 students were able to clearly define what a CE looks like, with local, national and international examples). For a very short, 10-week pilot, this was deemed a great success and the project will soon be available online, for free, for all schools in Brighton & Hove to utilise as part of their teaching until 2027. It is hoped that this additional, free resource for schools in Brighton & Hove will not only reinforce and bolster their existing sustainability/eco/environmental education for all, but also re-frame it through a deeper and more detailed lens of the CE. Embedding this 'roundness' to the 'reading, writing and arithmetic' as a foundational academic skill could open up a huge acceleration in the applicable, future-proofed skills and knowledge our next generations require to not only survive, but thrive.

3 THE CIRCULARITY GAP AT UNIVERSITIES – WHAT WE SEE NOW
As of March 2023, there are currently 25 'profiled universities' on the leading CE research charity, the Ellen MacArthur Foundation website. These universities are listed as being involved in the CE in different ways, from 'teaching to campus management' [10]. However, regarding the taught elements of the CE in the context of each university, there is a huge variety of involvement between institutions. The CE is often seen as 'subject niche' and whilst there will certainly be many more courses across the UK that incorporate the CE in some minor ways there are more natural subject areas where CE teaching currently fits in universities, such as courses within schools of Business and Economics, Design, Engineering and International Development. However, there is a growing outcry by students across all disciplines of how they are not being equipped with the information needed to thrive in their changing world – and that this 'specialist' knowledge should not be confined to selected subjects. This was demonstrated by the Nov 22 announcement by the University of Barcelona on how from 2024, all 14,000 students will take a mandatory climate crisis module – a decision that is thought to be a world first - made following a week-long protest and sit in by climate activist group 'End Fossil Barcelona'. The new 125-hour course, (50 hours study in class plus 75 hours study at home) will include not only traditional climate science-based learning, but the social, economic and ecological aspects of the climate crisis. [11] Many aspects that incorporate and are solved by elements of the CE. From 2024, all University of Barcelona student will leave with a new, foundational skillset/knowledge, however, the fact that this course has been hailed a possible 'world first' clearly shows the void we currently have in HE.

3.1 The role of design
Product Design is fortunately one HE subject area where elements of sustainability have been traditionally taught as a core skill in course curricula for a longer time. As creators of often physical 'things' there is a large responsibility on the designer – especially as according to the 2012 Ecodesign study by the European Commission, up to 80% of a product's environmental impact is decided at design stage. [12] This responsibility continues to accelerate for the designer, with a growing global, wealthier population of middle-classes. Same day, one click purchases have become the norm for many and demand for and access to 'stuff' has never been higher. We have the responsibility as educators to ensure that all our graduating students understand the nuances of the CE – a system that they will invariably be working towards (or eventually within) in industry. Plus, studies such as by De Ios Rios and Charnley demonstrate how design skills have to change to create a working CE in industry. [13] As well as a

foundational life skill, as was explored in the ARB&H project in younger students, at HE level, this knowledge becomes a critical employability skill.

3.1.1 Future-proofing students

Within the BSc/BA courses at the University of Sussex the critical approach of CE knowledge ‘gap-filling’ has been taken. In the final year module ‘The role of Design in the Circular Economy’, students are taken on an 11-week journey through CE principles such as waste stream identification and implementation in new products, designing for disassembly, repair and reuse, the rental economy, material supply chains, LCA’s, doughnut economics, brand transparency, greenwashing, individual incentivisation and behaviour change, business models and legislation. Whilst the very purpose of this module is to equip students with the CE language and practices to implement them in their work (and onwards in employment), an 11-week module with a location specific research-based brief is certainly not enough. Circularity has therefore been embedded in earlier Y1 and Y2 modules in more foundational ways – especially around understanding components/assemblies, construction/manufacturing techniques and material selection. Even a prototyping module in YR1 has removed all materials that are not able to be reprocessed/reused (such as blue modelling foam) and prioritises the use of waste or easily recyclable materials. 3D printing is still encouraged, but at later stages, when form may be more refined through other, simpler modelling techniques – and therefore prints are less likely to fail and be discarded straight into the recycling bin. Other modules introduce concepts of biophilia and environmental regeneration, or within live briefs with industry to explore the concepts of plastic and packaging reduction, or consumer waste reduction – all explained to students within the global context of the CE as well as how it relates to their own design practice. However, many of the CE aspects that are taught on the University of Sussex BSc/BA courses could easily have been covered in earlier education – indeed many of the simpler elements were demonstrated in the ARB&H pilot to be both understood by and applicable to students as young as KS2.

4 CONCLUSION – WHERE WE GO NEXT

This therefore opens a discussion. At present we see either a complete void of CE knowledge in some HE subjects, or very subject specific attempts to educate students in how the CE relates to them, along with some foundational knowledge that these specific elements rest upon. Although the CE will undoubtably form a global, central role in all our future lives, many students are being left out, or left behind in their understanding of the CE due to it not relating as obviously to their own subject specialism at HE. So, what if we saw a widespread integration of the CE as foundational knowledge to *all* learners in earlier education, like the ARB&H pilot project? Instead of universities taking on the current role of gap-filling this knowledge and tackling raised eco-anxiety from lack of understanding and personal empowerment, entrants to HE would already have a wide and varied, embedded knowledge of the CE. We would be able to teach and actively *advance* CE practice, accelerate understanding and research in all fields, and create faster impact on industry as deeper empowered and knowledgeable graduates enter the workplace. Graduates of today are the active change makers and circular creators of tomorrow – and if this new skill, the ‘roundness’ of circularity was indeed added to the existing ‘R’s of ‘reading, writing and arithmetic’ of earlier years, HE institutions could help push and create a positive, regenerative future faster than ever before.

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MATCHING VALUES AND ALIGNING GOALS IN THE INITIATION OF BUSINESS RELATIONSHIPS

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ABSTRACT
This study had the aim of finding sought after values in collaborations between start-ups and consultants from large agencies. It was placed in the context of Skills-based volunteering (SBV) and the initiation of a collaboration between the two parties, facilitated on a matchmaking two-sided platform, which is designed by the two first authors. The study tried to respond to the following questions 1) why a platform immediate this cooperation and, 2) how to design for matching values to generate trust? The authors firstly discuss theory and empirical research regarding challenges of initial user acquisition to multi-sided platforms. Secondly, a design project is presented focusing on developing a platform to facilitate more collaborations between start-ups and consultancies in Norway by creating mutual benefits. The article contributes to generate knowledge on how to improve, enhance and manifest SBV collaboration. This is also a topic for future design education, which should add more emphasis on collaborations between start-ups and consultancies and adjust education towards possibilities and trends in SBV.

Keywords: Matchmaking, start-ups, consultants, shared values, business initiation

1 INTRODUCTION
Norway is facing a large societal shift with a growing population of elderly and a shrinking oil and gas industry. Start-ups can contribute to developing radically new products and services [1] and hence might play a significant role in meeting socio-economic shifts in the years to come. Yet, 73,5% of startups in Norway are insolvent within the first 5 years [2] and one of the main reasons for this is the lack of IT competence [1]. In Norway over 3000 IT jobs were not filled in 2020, and companies are dependent on importing IT related competencies [3]. Many authors claim that knowledge is a resource that can be traded, sold and like IT competencies – imported. It can also be donated or gifted away for example in the form of skills-based volunteering for example by consultants between assignments, or by newly employed team members. However, non-billable time is sometimes regarded as 'worthless' and is often unstructured [4]. According to [4] approximately under 35% consultants viewed their non-billable time as used constructively and less than half of the time was spent on activities that were planned and goal directed. Consequently, consultants use a significant part of their non-billable time on activities that don't create value for them, or anyone else. These knowledge resources could be used in Skills-based volunteering, and especially when related to IT, might be able to meet some of the demand for start-ups. The second section of this article explores skills-based volunteering to utilise surplus knowledge resources in IT consultancies to make more start-ups succeed. The third section presents a design project on developing a platform to facilitate collaborations between start-ups and consultancies in Norway by creating mutual interactions. Section four discusses challenges and benefits of the platform and section and possibilities for start-ups, consultancies, and society in general. Conclusively section five summarises findings and discusses SBV as a topic for design education and research to improve academia-stakeholder collaboration.

2 REASONS AND POSSIBILITIES FOR SBV
Even though a business's top priority is to generate wealth for its owners and shareholders, community engagement becomes increasingly relevant. This concept is often referred to as Corporate social responsibility (CSR). [5] defines CSR as 'actions of the firm that advance some social good, beyond the immediate interests of the firm and its shareholders and beyond that which is required by law.' [6] (p. 132) Skills-based volunteering is one form of CSR where an employee donates valuable expertise. At

the same time, the employee learns from the experience and gains new skills, which ultimately also benefits the company which donates [6]. The same authors define SBV as ‘a strategically driven activity that involves employees donating job-related skills and acquiring or developing skills through voluntary contributions to an external non-profit organisation that requires certain skill sets.’ (p.3). The highest gain through SBV were interpersonal skills. 78% of companies in their study reported in a study by Vian, McCoy, Richards, Connely, and Feeley [7] (2007) that their employees gained ‘professional and personal skills’. Booth, Park, & Glomb, [8] (2009) found that 79% of the survey participants had gotten better at interpersonal skills. A formal setting is important for SBV [9] and if an employer markets these formal volunteering programmes as a way for their employees to gain skills, there is a higher rate of participation [9]. Learning return increases with the time spent volunteering [10]. The perceived safety of the learning environment plays a significant role when acquiring new skills or practising old ones [10] and volunteering programmes often provide this [11]. An example given by Dempsey-Brench & Shantz [6] is Deloitte’s IMPACT Day, where employees get the opportunity to practise work-related skills in a safe environment while doing something for the greater good. Dempsey-Brench & Shantz [6] (2021) found however that some volunteers did not like the gained experience and skills from volunteering but meant it was immoral to gain something when you were supposed to give. Conclusively, the benefits of employees and companies depend largely on the collaboration with the receiver. Cook and Burchell [12] (2018) found that both gain more from SBV if the collaboration is good and leads to in-depth collaborations [12]. To find the right match between companies and receivers the design part of this course developed a brokerage platform between IT consultants and start-ups that ensures a good balance between supply and need. This solution is getting more and more common [12]. The mechanisms presented in {Table 1}illustrate interactions and touchpoints in business relations that are relevant when designing a platform and designers can use them as initial starting points when designing interactions. While this summary proposes a framework for how to initiate relations, designers should not assume that trust and trustworthy actions are designed simply by using a system [13].

3 DESIGNING FOR TRUST

Generating sustained trust is one of the deciding factors of successful partnerships [14], especially when facilitating the exchange of knowledge and information [15] such as in SBVs. The project presented in this article, “Muttu”, is part of an assignment in the PD9 course at the Department of Design and comprises a theoretical and a practical part. Muttu is a platform designed to motivate users to share their knowledge and skills, contributing to the ease of interaction [16]. This will help reduce the transaction cost of social interactions when forming business relationships[18]. Dibben, [15] (2000) explains how, if executed well, trust reduces the complexity, uncertainty, and transactional cost between business relations on a platform. Evans & Schmalensee, [16] (2013) describe how, when designing a platform, it is important to manage processes and paths of relationally embedded ties to grow firms. Relational embeddedness between relations has three benefits 1) trust in each other’s competence, 2) social trusts and 3) goodwill trust as highlighted by Hite [18] (2005). The mechanisms in {Table 1} below illustrate an evolution between trust building stages which may be considered when designing a platform for establishing SBVs. These mechanisms are developed through extensive literature search on platforms, trust and network effects. They suggest a framework for how to initiate relations, while it is important to mention that designers should not assume that trust and trustworthy actions are designed simply by implementing the mechanism [19]. In total sixteen mechanisms were found across thirty relevant articles from within the domain.

Table 1. Mechanisms and functions in preinitiation and initiation phase

Mechanism of matching values	Function
Preinitiation phase	
Discussion of self-interests and collective interests	Communicating one's own interest and finding collective interests
Map out internal competences	Identifying complementary assets
Map out roles of influencers, decision makers etc.	Clarification of which person does what
Assessment of readiness level of technology	Identifying tasks and costs associated with production
Open communication of difficulties and challenges	Allocation of correct resources
Develop a shared roadmap of non-confidential aspects	Facilitates communication with potential partners
Communicate needs through sharable roadmaps to position the start-ups with complementary resources.	Position technology with complementary resources needed
Monitor and inform upcoming milestones and their criticality	Contributes towards predictability

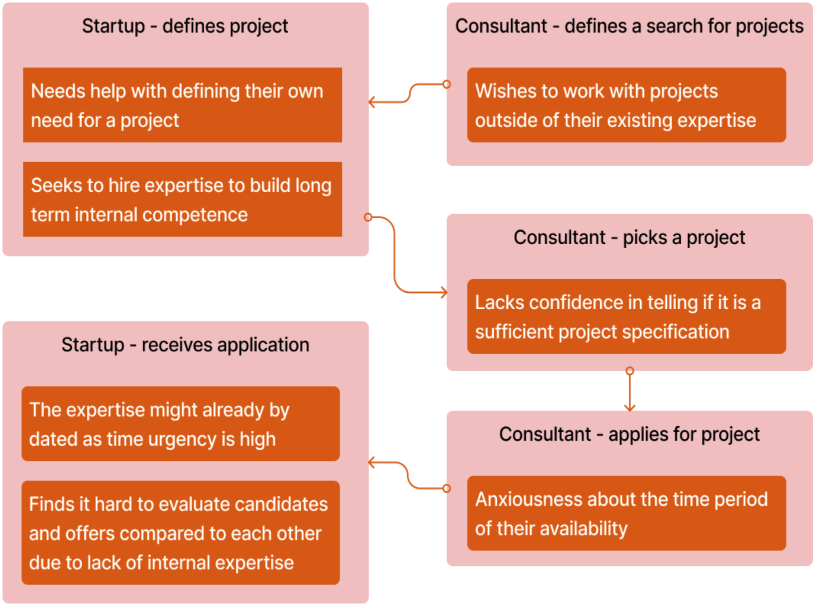
Initiation phase	
Learn about each other	Decreasing distance between parties
Attitudinal input	Creates safeguards as an effect of shared values
Face-to-face communication	Contribution towards trust development
Utilize a joint history of interactions	Mitigates learning about each other´s competence
Aligning parties' interests related to the relationship.	Reducing conflicts
Develop systems of rewards and penalties	Learning about each other
Simplify coordination	Making more efficient information exchange and uninterrupted learning
Sharing responsibility of project management	Easing communication and decreasing perceived asymmetry
Establish goals for skill development	Developing skills
Develop corporately aligned goals	Starting a valuation of collective benefits above self-gains
Capture non-confidential aspects as a roadmap for communication	Identifying factors that may change the business model
Create engagement other than formal meetings	Getting a feel for the start-up culture
Schedule regular review meetings, updates, etc.	Managing the partnerships processes
Agree early on overarching principles	Clarifying expectations
Document all interactions	Ensuring track-record in case of disagreements
Manage transitions	Creating consistency throughout changing participants of the relationship
Review the partnership	Provides insight to strategical review processes

4 PLATFORM DESIGN

The main goal of Muttu is to facilitate a more efficient use of knowledge workers by connecting the need for specific technical expertise from start-ups with a supply of it coming from Norwegian IT consultancies. The design part of Muttu includes development and deployment of a digital matchmaking platform. The proposed value proposition of Muttu highlights consultancies´ chances for showing a societal contribution while adding valuable experience to their portfolio, and ultimately helping more start-ups succeed. To achieve continuous and accurate development, a user-centred design approach has been employed for the initial platform structure and interface design. The project has also used the three design lenses for innovation popularised by IDEO to reflect upon the different aspects of development. Throughout the design work potential end-users have been included from both sides of the platform through interviews and a workshop. In total 7 start-ups and 7 consultancies, all from Norwegian industry, have participated to develop this project. 50 conversations with potential users through sales of the platform have also contributed to learning to know the user better. A literature study observing both social and societal aspects of skill-based volunteering has helped lay out the background of the project, anchoring it in theory. Resulting insights from interviews with both startups and consultants defined pain points {Table 2} for both parties to address when designing the platform. One of the crucial factors for startups, that the authors wish to highlight in this paper, is a reverse proportional coherence between their ability to submit well-defined project specifications and their size. This means that more mature companies could sufficiently define a project's length, complexity, and requirements whereas newer companies struggle in doing this. From the consultant's side it is worth highlighting that this user group needs predictability when taking on projects like those relevant to Muttu´s services. The reasoning being that leaving a project prematurely is damaging to the reputation of both the individual consultant and the consultancy.

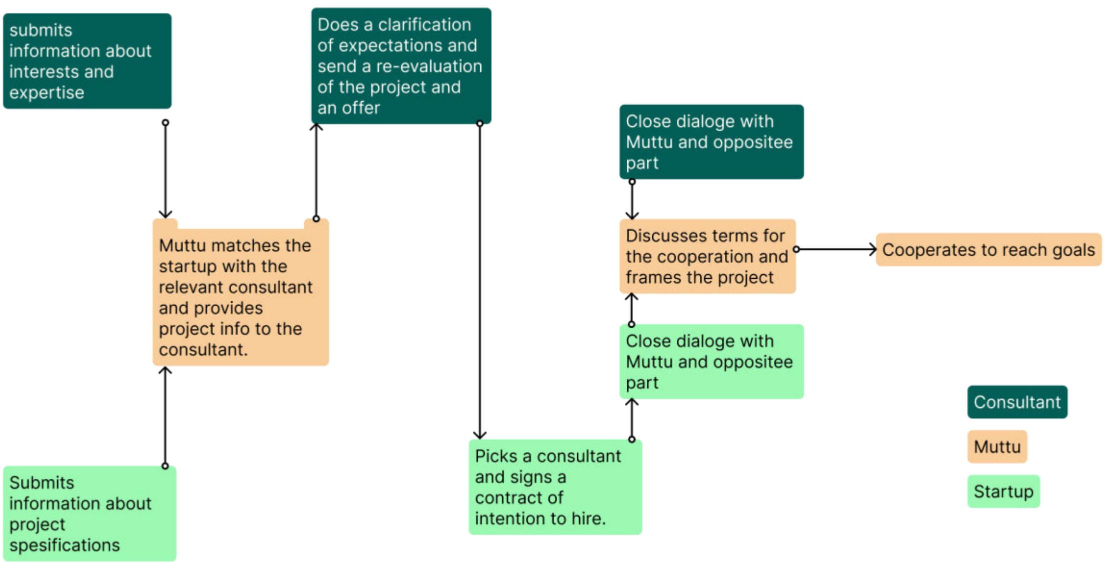
The requirements for the design of the service provided by the platform were developed based on feedback from end-users to guide the project and to function as criteria to measure the performance of our flow. A list of five requirements were highlighted by the authors as the most important ones. 1) The process should be as short and precise as possible, 2) startups should be able to better specify their needs and projects, 3) startups should have increased possibilities of comparing consultants when hiring, 4) consultants should have increased efficiency in communicating their expertise and availability to startups, 5) consultants should to an increasing degree be able to choose between projects aligned with their interests. By combining the mechanisms from {Table 1} with our requirements, we designed the service flow of the digital platform as illustrated in {Table 2}.

Table 2. End-users pain points related to the service flow



The outline of the service flow (see Table 3) is aiming to build trust and to benefit start-ups in hiring talent through information sharing within the process. First, information about the start-up's needs for a project or period is described and delivered to Muttu simultaneously as consultants register their expertise and availability.

Table 3. Muttu´s service flow



Currently, Muttu uses this information to match the two parties together. In the future it is planned to be a semi-automatic matchmaking process using algorithms. After matching the parties together in pairs, Muttu suggests start-up projects to consultants based on their expertise and interests. Within this match there is information about a non-confidential roadmap of the project, as well as information about competencies which should contribute to building a trust in competence. The consultants will then comment on and possibly change the project specifications through a roadmap and project description, before submitting a proposal to the respective start-up chosen. This step is meant to reveal an initial commitment and align both parties' goals. Finally, the start-up selects an individual or a team of consultants for their temporary hire before arranging a face-to-face meeting physically or digitally together with Muttu as a third-party actor. Together a discussion about terms and conditions about the cooperation is facilitated before the actual work is executed. Currently, as of February 2023, the platform is in its testing and developing phase while a pilot project is conducted. The digital product is being evaluated by end-users while being developed in parallel to reach a goal of releasing a beta-version within May 2023. The pilot is a closed alpha where different steps of the service's processes are carried out manually by people from within the company.

5 BENEFITS AND CHALLENGES OF THE PLATFORM

The platform is functioning as a brokerage between the two parties, and this comprises challenges and benefits for the users, the value created and the learning experience. As a brokerage, the platform can largely dictate who can use it, and what they can use it for. This creates a safer environment for fragile start-ups to thrive, as the platform can ensure that untruthful consultants get kicked out of the platform. It can also create a safe and effective learning environment as consultants can choose which start-ups they want to work with and can see the same information from all of them and make a more informed choice. The platform also ensures better quality control over what the start-up needs help with. By engaging in collaborations without the platform, the information shared between the two parties are not quality checked. On the platform, both the case the start-up provides (the learning opportunity for the consultant) and the expertise the consultant provides (the help the start-up needs to solve their problem) are guided, so the two parties know what they get to a larger degree. The largest benefit in the context of learning is that the platform facilitates learning in a real situation. The consultant can learn in an environment that is in the real world which is much closer to the situation they need to use their newly gained skills in their work afterwards. By fusing a learning activity with value creating activities, the consultant gets a much larger toolbox of arguments of why they should engage in the activity, and they create value for the community There are also some negative sides of creating a platform like the one presented in this paper. The first, and most preeminent, is that the consultant needs to have basic knowledge of the thing they want to do on a case presented by the start-up. For the service to bring value to the start-up, the consultant needs to have expertise to offer the start-up. At the same time, the consultant needs to gain new skills or knowledge for it to be worthwhile. There is also a limit on what learning categories can be offered, and for whom. Not all skills can be gained through this method, and not every industry can use the platform to gain new knowledge.

6 SUMMARIES OF FINDINGS AND EDUCATION POSSIBILITIES

Start-up's need consultants who know of the start-up's situation when hiring. This suggests that consultants which know the domain that the start-up is working within are favourable and maybe crucial. Start-up's also highlight how they prefer hiring long-term employees as it contributes more towards building internal expertise within the company. When hiring short-term employees' start-ups mention specific tasks that are well defined as a possible solution to their problems. From the consultants´ side the importance of information about the project was highlighted. Meaning sufficient information about duration, relevance, payment, and goals for the project is necessary to decide on whether an allocation of a consultant's time is worth it or not. It was also highlighted that consultants need sufficient information about the details and goals of the project, as they need to set up specifications for the project before taking on the work. Lastly it is important to mention that consultants often want to work within a domain or task from outside of their expertise, which in turn will affect the supply of expertise on the platform.

Conclusively, connecting different economic stakeholders for exchange and knowledge generation on a voluntary basis is comparatively new in design education but the platform development project contributes greatly to develop innovative design management and collaboration approaches. Socially, skills-based volunteering in companies impacts for example sustainable transitions, technically collaborative platform design responds among others to the new paradigm of agents-based technology that replaces object-oriented design [20]. Agent-based modelling is a relevant method for design education for both interaction design and design management. For NTNU design curricula this relates especially to the MA course TPD4166, Design strategy, where students are required to develop innovative processes with organisations to facilitate communication and interaction, thereby learning to manage strategic design processes. Designing collaborative design management platforms for e.g., IT consultants and start-ups as in the case above does not just facilitate interaction of different actors but also allows to pool regional and national forces and make use of intellectual resources in a time that is globally constraint by economic and political drainage.

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MATERIAL FUTURES: AN INTRODUCTION OF REGENERATIVE DESIGN PRINCIPLES TO PRODUCT DESIGN STUDENTS

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ABSTRACT
Our material world and consumer habits have a significant negative impact in the environment. Across its life cycle the average product results in carbon emissions of 6.3 times its own weight (1). Designers are developing biomaterials from waste or generating renewable growable materials rather than extracting and mining.
Materials developed from mycelium, bacteria, algae, and cactus help to reduce the environmental impact of single use and to rethink our relationship with convenience and consumption. These materials offer some of the insulating, lightweight, waterproof, and transparent properties of plastic, but are non-toxic and compostable. Moreover, these materials often use bio fabrication techniques, instead of traditional manufacture processes, by harnessing biological organisms to design and grow products and clothing.
Truly Regenerative Design considers interconnected dynamics that are people and planet centred with a focus on circular economy and regeneration. Material Futures used biomaterials and bio fabrication to introduce Regenerative Design principles to second year Product Design students, towards a co evolutionary process between humans and natural systems, understanding of local context and a living system thinking approach. Students were asked to design a product made entirely of mycelium that considered user needs whilst helping to decarbonise the material world. Design methods such as cone of futures, future back casting and the thing of the future were used so students had to consider future micro and macro impact of their proposals. The project was supported by a Regenerative Design Studio Lab through a workshop, in which students had the opportunity to learn mycelium's bio fabrication processes and properties. The paper includes examples of experiments with mycelium in class, the methods used for concept development and student feedback, that illustrates the importance of introducing Regenerative Design principles to increase ecoliteracy and consequently reduce the environmental impact of product design.

Keywords: Regenerative design, bio fabrication, living systems approach, ecoliteracy, future back casting

1 GREEN VS SUSTAINABLE VS REGENERATIVE DESIGN

1.1 Regenerative design definition
According to the Regenesis Group definition, Regenerative Design uses a living system thinking approach. It generates resilient and equitable processes that regenerate rather than deplete underlying life support systems and social ecological resources. In summary, it encourages to 'design capability instead of designing things' (2) shifting the focus from objects to nurture relationships with the wider context. Although, the notion of Regenerative Design has been lingering since at least 1970, there has been a recent re-evaluation of what sustainable development means and how Regenerative Design can be used to go beyond mitigation.

1.2 Difference between Green, Sustainable and Regenerative Design
There are important distinctions between the concepts of Green, Sustainable, and Regenerative Design. These distinctions are important to how product design lecturers convey environmental education, increase ecoliteracy and the impact it has on future design graduates.

Green Design is centralized around specifically decreasing environmental impact from human development, as Van Der Ryn wrote ‘Green Design only slows the rate of destruction’ (3).

The definition of sustainable or **sustainability** has been widely accepted as the ability to meet the needs of the current generation without depleting the resources needed to meet the needs of future generations. However, this definition emphasises an anthropocentric view as explained by Raymond J. Cole. The current sustainability modus operandi ‘is allowing technological and engineering processes that perpetuate a mechanistic worldview and its limitations in dealing with complex and living systems, that are bringing both Green and Sustainable Design to an evolutionary dead end’ (4). Sustainable Design focusses on using fewer resources and producing less waste and pollution by incremental change but still leads to negative environmental impact and fails to include local context, leading to a neutral and zero waste framework instead of a positive impact one.

A **Regenerative Design** system ‘takes advantage of flows and feedback loops that allow for greater adaptability’ (5). The key distinction of Regenerative Design is that both humans and natural systems are ‘viewed as partners and need to co evolve’ within a certain context, meaning that humans depend on the integrity and health of natural systems that they live in (4). In sum, Regenerative Design goes beyond the green and sustainable principles of measuring environmental, social and economic impact and generating mitigating solutions. Instead, it aims to understand a specific place and its unique patterns, design reciprocal relationships with living systems and create a culture of co-evolution (6).

1.3 Ecoliteracy

In 1990 Professor David Orr coined the term ‘ecoliteracy’, describing the ability to understand the complex natural systems that enable and support life on Earth. Orr’s findings concluded that the more ecoliterate the more likely people would change their behaviour towards a co evolutionary process with natural systems. Sustainability, along with environmental education, is a key requirement of most design programmes worldwide. However, as Hempel described, ‘knowledge is not enough’ (7). Studies about the effectiveness of environmental education conclude that leads to polarisation. Ecoliteracy, can conveniently skirt moral and political issues, but when it is treated in the broader context of environmental education, ‘the issues of personal responsibility and social equity become inescapable’ (7). Hempel shows that the factors that contribute to eco-complacency and disbelief, amongst others, are psychological distance – e.g.: human separation from natural world– and technological insulation – e.g.: technology will provide the solution to all negative environmental impact. Much attention in environmental education as concentrated in ‘knowledge deficit’ and not so much in ‘behaviour deficit’. Therefore, How can design lecturers introduce more robust Regenerative Design principles within Product Design undergraduate programmes in U.K.?; How do we overcome eco-complacency in environmental education within product design?; and How do we go beyond sustainable literary?.

2 MATERIAL FUTURES

2.1 Knowledge is not enough

The premises of the Material Futures brief were to introduce Regenerative Design principles to undergraduate product design students and to increase ecoliteracy focusing on improving psychological distance and avoid technological insulation.

As part of the Design Futures module second year product design students were asked to design a household good made of mycelium. Over the past decade, the use of mycelium in product design has gained popularity due to its unique and sustainable properties, it has been used in packaging, insulation panels, clothing, vases, and lighting shades. Mycelium is a root like structure of fungus that combined with a substrate can grow and form complex structures without the need for external inputs such as water and sunlight, making it highly resource-efficient and durable material that can withstand wear and tear (8).

Students had approximately 4 intense weeks to explore future mycelium applications and consider user needs and local context, in addition to harnessing the potential of biological organisms. The project was supported by a Regenerative Design Lab: Osmose Studio. The studio delivered a lecture, a hands-on workshop and provided mycelium along with technical support, so students could explore the material first hand (Figure 1 to 3).

Students were strongly encouraged to question 'throw away and convenience culture', a behaviour so ingrained in the western society that has been difficult to shake off. It is predicted that by 2050 as much as 12 billion tonnes of plastic will have accumulated in landfills or the natural environment.

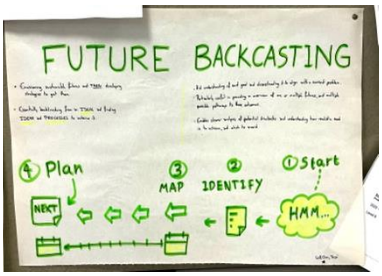


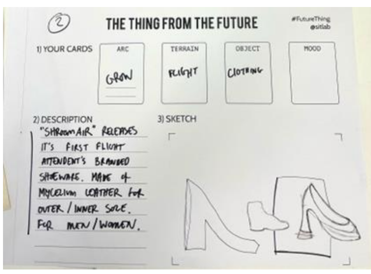
Figures 1. to 3. Mycelium workshop by Osmose Studio

2.2 Methodology

The project was divided in 3 stages. During **stage 1** students were exposed to biomaterials, bio fabrication concepts and principles of Regenerative Design. The mycelium workshop aimed to address phycological distance as students had the opportunity to experiment and manipulate with a living organism. There were 6 Regenerative Design principles covered within the project: 1. positive impact in ecology, society and health, 2. use of biomaterials and bio fabrication processes that harness the potential of biological organisms, 3. local context and data, 4. design 'capability' instead of 'things', 5. involves a community and or a specific user group on a continuous basis and 6. considers the wider context and unintended consequences. These principles were based on Regenesis Group framework for regenerative development (2).

Within **stage 2:** concept development, methods such as: cones of future, future back casting, and the thing from the future, were used to spark debate and question how some sustainability principles such as recycle can lead to negative environmental impact. The first method used was futures cone, through outlining preferable and probable future scenarios, once that was defined, students started working backwards to identify strategies that connect future to present, in this specific case how to create a culture of co-evolution between humans and mycelium (future back casting method). Within this method students were encouraged to explore concepts of convenience, single use within bio fabrication (e.g.: if we use biomaterials do we need to worry about single use?) and negative environmental impact offset strategies. In addition, students drafted a system map that considered the local social and health context of their proposal and unintended consequences to natural systems. Besides future back casting, The Thing from the Future game, created by Situation Lab, was introduced to students. Players were challenged to work collaboratively, in small clusters, to describe objects from a range of alternative mycelium-based futures and generate design proposals to randomly allocated scenarios. This stage was highly enjoyed by 85% of the students as per project feedback (Figure 4 to 6).



Figures 4. to 6. Stage 2 concept development included Future Cones, Future Back Casting and The Thing of The Future methods

Stage 3 involved aligning design proposals to the 6 Regenerative Design principles (described in stage 1) and apply a system thinking approach. To support students on this we asked them to highlight the most important principles in relation to their ideas and provided a table in which they could rate the inclusion of the regenerative principles and check whether they could improve it.

3 VALIDATION, RESULTS & FEEDBACK

The study was validated through triangulation of data and methods. Data collection methods included a survey, students' comments throughout project stages, discussion groups/ roundtables and lecturers' observations.

Material Futures aimed to increase ecoliteracy, with a focus on improving psychological distance and avoid technological insulation. To improve psychological distance the project allowed hands on experimentation with mycelium through a workshop and subsequent growing process. Before the project 86% of the students never heard about the potential of mycelium as a biomaterial as compared to 100% knowledgeable after the project (Figure 7). Moreover, 60% of the students considered the workshop extremely useful to their learning experience and their feedback was encouraging: 'The Osmose presentation for the project was really helpful in understanding the makeup of the Mycelium. Overall, the project was fantastic' (9) and 'The workshop was good and provided all essential info, the only thing I would add is a deeper look into other ways of manufacturing mycelium' (9). Regarding the use of biomaterials in other future projects, 60% of students stated they were likely and 40% very likely, due to the positive environmental impact.

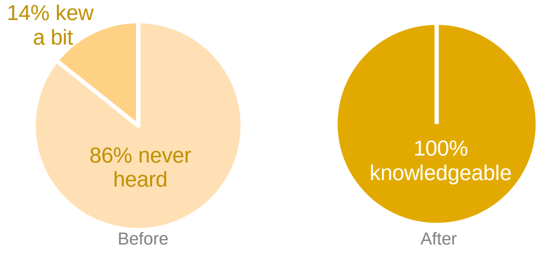


Figure 7. Student feedback on how knowledgeable they were before and after the project about the potential of mycelium as a biomaterial

In terms of understanding technological insulation and how to avoid it to decrease eco-complacency 42% of students mentioned that single use products should be avoided even when using biomaterials and bio fabrication processes with another 42% having a neutral stance. Similarly, 60% of the students demonstrated the importance of shifting from designing 'things' to design 'capability', with 72% of them showing evidence of unintended consequences of methods and processes as per the following student comment 'even when using biomaterials there is waste and manufacturing processes that require energy, and designers need to be aware the impact' (9).

The acquisition of Regenerative Design principles was assessed through Material Futures student survey and how students' projects outcomes aligned with regenerative principles. The knowledge of Regenerative Design was assessed before and after the project, with 57% of the students stated they 'knew a bit' of Regenerative Design before the project compared to 86% agreeing to be 'knowledgeable' about Regenerative Design after the project.

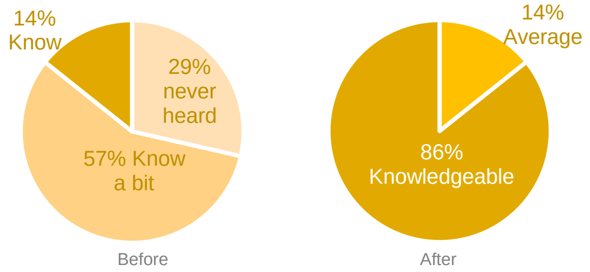


Figure 8. Student feedback on how knowledgeable they were before and after of Regenerative Design principles

However, as ‘knowledge is not enough’, to evaluate in depth the effectiveness of the introduction of Regenerative Design, students were asked to rate how their proposals aligned with the 6 Regenerative Design principles covered within the project.

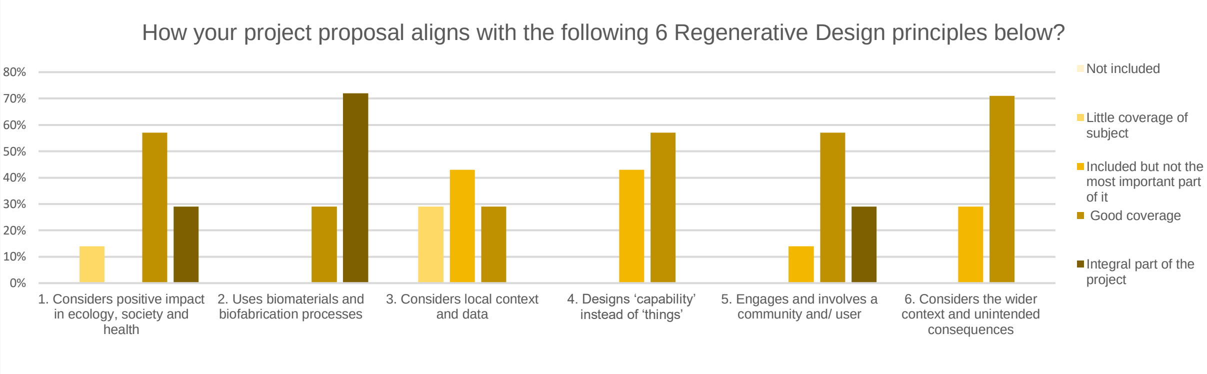


Figure 9. Student self-evaluation on how their project proposal aligned with the 6 Regenerative Design principles covered within Material Futures project

The use of biomaterials and bio fabrication processes was an integral part of the project for 74% of the students. Considerations about the wider context had a good coverage for 71% of the students. A total of 57% said their project had a good coverage of the positive impact in ecology, society and health, design ‘capability’ instead of ‘things’ and engages and involves a community and/ user. The principle that students thought had less coverage was considerations about local context and data, with 43% acknowledging that was not the most important part and 29% saying that had little coverage. In order to cross analyse students’ opinions to project outcomes, a comparison table was generated below (Table 1).

Table 1. Analysis of how Regenerative Design principles were included in students’ project outcomes

	Students' projects											Total of score per principle
Regenerative design principles	A	B	C	D	E	F	G	H	I	J	K	
1. Considers positive impact in ecology, society and health	1	1	0	1	1	1	1	0	1	0	1	8
2. Uses biomaterials and biofabrication processes	1	1	1	1	1	1	1	1	1	1	1	**11**
3. Considers local context and data	0	1	0	1	0	1	1	0	0	1	1	6
4. Designs ‘capability’ instead of ‘things’	0	1	0	1	0	1	0	0	0	0	1	4
5. Engages and involves a community and/ user	1	1	1	1	1	1	0	0	1	1	1	**9**
6. Considers the wider context and unintended consequences	1	1	0	1	0	1	0	0	0	1	1	6
Total score per project	4	**6**	2	**6**	3	**6**	3	1	3	4	**6**	

The results, concerning the principles that had an integral part in the project, the use of biomaterials and bio fabrication processes and involving a user, were similar to student self-evaluation (Figure 9), but differed from students’ perceptions on designing capability instead of things and considerations of the wider context and unintended consequences.

4 CONCLUSIONS

How can design lecturers introduce more robust Regenerative Design principles within product design undergraduate programmes in U.K.?

The project was successful in imparting principles of Regenerative Design to design students, especially in harnessing the potential of biological organisms with bio fabrication processes as well as considering a user and /or community. The brief focussed on designing reciprocal relationships with living systems (in this specific case mycelium) and the use of biomaterials, that is evident in both students’ feedback and lecturer’s analyses.

Other principles such as the consideration of the positive impact in ecology, society and health and the wider context and unintended consequences were covered mainly in stage 2 during future back casting and the thing of the future methods, and although student feedback shows a good coverage of these principles, project outcomes indicated that it could be improved. However, students' perceptions demonstrate that the discussions in class around it were relevant and can be emphasised at a practical level. The principle that was more difficult to evaluate was design 'capability' instead of 'things', as students were more inclined to take a product solution approach and found difficult to integrate a system thinking model. Also, the brief directed the students to design a household good made of mycelium, a prescriptive approach might facilitate considerations of the wider context of their products. Overall, the results reveal that using biomaterials and bio fabrication processes enables the acquisition of regenerative principles.

How do we overcome eco-complacency in environmental education within product design?

The opportunity to experiment with materials and bio manufacturing processes was efficient to overcome psychological distance, this was one of the most enjoyable parts of the project as per 86% of the students. In terms of legacy, in order to evaluate how these principles will be applied in other modules and future projects, it requires a longitudinal study. However, results are promising with 57% of students saying that they are likely to apply Regenerative Design principles in the future.

How do we go beyond sustainable literacy?

Material Futures project was a good starting point. By setting up a practice-based brief that focussed on Regenerative Design principles, students were exposed to concepts that otherwise they would not have the opportunity to learn. In discussions during stage 2 sessions, methods such as future back casting and the thing of future enabled 86% of students to question current sustainability literacy. However, it will require a profound re design of the product design curriculum to include Regenerative Design principles from level 4 to level 6. As per Hempel 'ecoliteracy will need to accommodate the traditional knowledge derived from nature-based attachment to place. Moreover, it will need to incorporate explicit social and economic concerns within an action framework that joins ecoliteracy with political literacy about governance' (7).

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INVESTIGATING THE PERIMETER OF INNOVATION IN DESIGN EDUCATION THROUGH MAPPING OF EXPERIMENTAL PRACTICES

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ABSTRACT

The term "innovative didactic" often describes the notion of a cultural and epistemological shift that can transform teaching and learning practices. Notably, the instructional design innovation implies a shift from traditional ex-cathedra teachings towards more active student engagement in the learning process. Recently, the pandemic and digital transformation have been among the main factors that have propelled the conversation about this topic. Design has always explored innovation in its didactics. By its very nature, design-based learning provides a teaching environment that places students at the heart of the learning process. There may be examples of these creative teaching approaches in the design literature. Still, no significant research exists on how design schools manage and monitor the teaching innovation process. Hence, this paper describes a funded research project "Innovation in Design Teaching", which aims to investigate the boundaries of innovation in design education in a situated context such as the School of Design in Politecnico di Milano. The study comprehends two research activities: the first is a survey delivered to every lecturer at the school in an effort to map the experimental approaches in the courses during the past decade, while the second one comprehends two sets of interviews. This paper summarizes the findings of the second research activity. The research contributes to understanding how experimenting happens in design schools and how this might contribute to didactic innovation. Hence, it provides a series of protocols that might be used in other contexts to expand the scope of the research.

Keywords: Design education, innovative didactics, experimental practices, instructional design, educational research

1 INTRODUCTION

Innovation of didactic is an increasingly strategic goal for universities to equip students with the right competencies for modern, complex challenges and continuously changing working contexts. Universities need to cope with preparing learners for jobs that still don't exist and be competitive towards emerging players in education and training [1]. In addition to the changing socio-economical working context, innovation in teaching practices is also affected by the historical transition from an objectivist to a constructivist perspective in learning science [2], [3]. Specifically, this shift informed the instructional design process suggesting moving from the conventional ex-cathedra lectures to a more active involvement of students in the learning process. More broadly, the research in this field aims to experiment with new educational practices and methodologies that relate pedagogy, space, and technologies and reflect on the synergies of the different elements with the users [4].

The formal acknowledgment of design education has its roots in the Bauhaus School, which aimed to teach design at the intersection of art, technology, and science [5]. The Bauhaus School's teaching methodology was derived from architecture and centred on the design studio and the project [6]. The design studio is a physical and interactive place where students may create design projects via interaction with other students and actual materials [7], [8]. Within this setting, the learning activity usually is driven by project-based learning. In project-based learning, students actively engage with actual, open-ended challenges and generate solutions via actions and reflections [9]. Thus, design-based education offers a teaching setting that places the students with an active role at the centre of the learning process and is open to integrating experimentation in the didactic. Examples of these innovative teaching practices

might be found in design literature. Still, there is a lack of extensive studies on how the teaching innovation process emerges and how these are being handled and tracked by design schools.
Within the described context, the research projects focused on mapping already implemented experimental teaching practices in the context of the School of Design of Politecnico di Milano to comprehend how these might inform new didactic practice in design education and translate into instructional design innovation. The experimental teaching practices during the research project have been analysed across 9 components that, according to Tassone et al. [10], help understand innovation as intended and implemented. These are the course-innovation characteristics adapted by Van Den Akker [11] curriculum components. The components described in table 1 in the methodology are the following: Rationale, Objectives, Content, Activities, Material and resources, Grouping, Location, Time, and Assessment. These interconnected components must be balanced for effective teaching practice implementation or redesign. Moreover, Van Den Akker [11] highlights how the relevance of the previously mentioned components varies according to the level at which it is discussed. In this regard, he outlined the following levels: a) macro level (i.e., society/state), b) meso level (i.e., school, institution), micro level (i.e., classroom/course), and d) nano level (i.e., individual).

Table 1. Components conceptual model was originally proposed by van den Akker [6] and then simplified by Tassone et al. [8]

Codes	Description
Rationale	We aimed to change the reasons why students learn
Objectives	We aimed to change the objectives towards which students learn
Content	We aimed to change what students learn (e.g., theories, skills)
Activities	We aimed to change how students learn (e.g., lectures, fieldwork)
Materials and Resources	We aimed to change with what students learn, both considering resources in i) digital format (e.g., video clips); ii) non-digital format (e.g., articles)
Grouping	We aimed to change with whom students learn (e.g., alone, in groups)
Location	We aimed to change where students learn (e.g., home, classroom)
Time	We aimed to change when students learn (e.g., prior to class, after class)
Assessment	We aimed to change how students are assessed (e.g., multiple-choice tests, field performance)

The first research activity focused on the micro level to analyse the teaching practice, while the second research activity expanded towards the meso level to comprehend how these two levels are related.
The data collected disclosed that various experiments are currently running in the context of the study, and they could contribute to understanding how design teaching and learning are recently evolving. In conclusion, the investigation developed in our situated context contributes to the discussion of understanding how experimentation in design courses can bring the innovation of didactic.

2 METHOD

The paper is based on a funded research project, Innovation in Design Teaching, to investigate the perimeter of innovation in design education. The research focuses on the situated context of Politecnico di Milano to comprehend how experimentation in university courses can lead to the innovation of design didactics. The study focuses on teaching practices, which are "the specific actions and discourse that take place within a lesson and that physically enact the approach and strategy" [12]. During the project, two activities were carried out: The first was a survey, briefly described, sent to all the lecturers at the School of Design of Politecnico di Milano, which aimed to map the experimental practices in the courses in the last decade. The second is composed of two sets of interviews. One set is a follow-up of the practices collected, and the second set is to relevant actors in the didactic organization to comprehend how the ecosystem can enable these experimentations. This paper intends to present the results of the interviews.

2.1 The survey

The primary research activity that has been carried out for the study has been the collection of past experimental teaching practices undertaken at the School of Design at Politecnico di Milano and their qualitative analysis. The purpose of the data collection was to reveal which experimentations were done in the study context and how these activities were presented. In June 2022, a survey was distributed to all lecturers at the School of Design to collect teaching practices. The lecturers were asked to reflect on the experimental didactic activities they developed. The obtained data served as the basis for the context-based mapping of experimental teaching techniques and implemented innovations [10]. The survey had three sections: the first aimed to comprehend the respondent's role, the second to illustrate the context (i.e., the course in which it was delivered), and the last section focused on the teaching practice. This last section had a first block to describe the didactic activity and a second to self-evaluate the practice according to nine components based on the Tassone et al. [10] revisited version of Van Den Akker et al. [11] curricular spiderweb (Table 1). This model has been chosen for its relevance in the context of instructional design and serves as a framework for the development of didactic across different levels. After being sent to more than 500 professors, 47 individuals responded to the poll. The majority of participants (n=42) mentioned only one teaching practice, a few described two (n=4), and one person detailed all three. 53 experimental teaching approaches were gathered and analysed in total.

2.2 The interviews

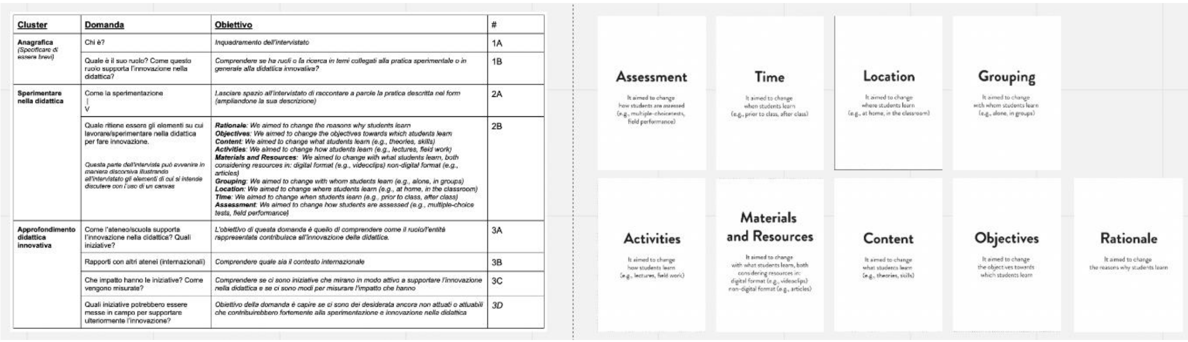
The second research activity that has been carried out for the investigation has been two sets of qualitative interviews. The first set aimed at deepening some relevant didactical experimentation, gathering further insights from the teaching team that proposed it, thus focused on the "micro" level (i.e., the level of the courses in which didactic activities are delivered). The second set of interviews aimed at comprehending the larger context in which these activities take place involving different points of view, thus focused on the "meso" level (i.e., the level of the school and the university, in which the didactic system is organized). Interviewees were selected using a "purposive sampling strategy" [13]. This strategy ensures the inclusion of specific categories of participants that may have an exceptional, distinct, or significant perspective on the phenomenon being studied (Table 2)

For the first set of interviews, the research team selected 7 teachers from the 53 respondents of the survey, looking for heterogeneity in the type of courses, diversity in the number of participating students, and variety in the disciplines covered. For the second set of interviews, the research team engaged 5 key players involved in organizing and developing the didactic offer to provide an overview of the didactic innovation trajectories within the Politecnico di Milano. Therefore, the interviewees for this set were: the previous Dean of the School of Design, the previous vice-dean and now current Dean, the director of the center for didactic innovation "METID", the didactic Delegate of the Department of Design and the rector's Delegate for didactic innovation.

Table 2. Interviewee overview

Micro Level	Interviewee Micro 1	Location, Activities
	Interviewee Micro 2	Activities, Assessment
	Interviewee Micro 3	Activities, Assessment, Content, Material and Resources
	Interviewee Micro 4	Activities, Assessment, Material and Resources
	Interviewee Micro 5	Grouping, Material and Resources, Assessment, Activities
	Interviewee Micro 6	Time, Location, Activities, Content
	Interviewee Micro 7	Activities, Rationale
Meso Level	Interviewee Meso 1	Current Dean (previous vice dean)
	Interviewee Meso 2	Previous Dean (during pandemic)
	Interviewee Meso 3	Head of innovative didactic Service
	Interviewee Meso 4	Rector's Delegate didactic
	Interviewee Meso 5	Design Dept's delegate didactic

The interviews were carried out by at least two research team members and lasted approximately 30 minutes each. Some interviews were done as web-call, while some happened in presence. In both cases, the protocol followed was the same. The protocol comprised questions and a series of cards (Figure 1). Moreover, the interviews have been designed with a semi-structured protocol to foster teachers' narratives of their experimental practices. The questions were structured into three sections: the first focused on framing the interviewee, the second on experimental practices, and innovating in didactic. The second section was based on the components previously presented. During this interview phase, the respondent was supported by using 9 cards based on the framework based on the conceptual model initially proposed by van den Akker [11] and then simplified by Tassone et al. [10]. The third section aimed at comprehending the relationship between experimental practices and didactic innovation. The questions vary according to the type of subject interviewed: more focused on the teaching experience for the first set of interviews (micro level) and more oriented on vision strategies and innovation trajectories for the second set of interviews (meso level). For instance, in the discussions with the key actor of the didactic system, the questions were not focused on a specific experimental practice but on how the system leverage on each component to innovate didactic.



Cluster	Domanda	Obiettivo	#
Anagrafica *(Specificare di essere brevi)*	Chi è?	*Inquadramento dell'intervistato*	1A
	Quale è il suo ruolo? Come questo ruolo supporta l'innovazione nella didattica?	*Comprendere se ha ruoli o fa ricerca in temi collegati alla pratica sperimentale o in generale alla didattica innovativa?*	1B
Sperimentare nella didattica	Come la sperimentazione | V	*Lasciare spazio all'intervistato di raccontare a parole la pratica descritta nel form (ampliandone la sua descrizione)*	2A
	Quale ritiene essere gli elementi su cui lavorare/sperimentare nella didattica per fare innovazione. *Questa parte dell'intervista può avvenire in maniera discorsiva illustrando all'intervistato gli elementi di cui si intende discutere con l'uso di un canvas*	***Rationale**: We aimed to change the reasons why students learn* ***Objectives**: We aimed to change the objectives towards which students learn* ***Content**: We aimed to change what students learn (e.g., theories, skills)* ***Activities**: We aimed to change how students learn (e.g., lectures, field work)* ***Materials and Resources**: We aimed to change with what students learn, both considering resources in: digital format (e.g., videoclips) non-digital format (e.g., articles)* ***Grouping**: We aimed to change with whom students learn (e.g., alone, in groups)* ***Location**: We aimed to change where students learn (e.g., at home, in the classroom)* ***Time**: We aimed to change when students learn (e.g., prior to class, after class)* ***Assessment**: We aimed to change how students are assessed (e.g., multiple-choice tests, field performance)*	2B
Approfondimento didattica innovativa	Come l'ateneo/scuola supporta l'innovazione nella didattica? Quali iniziative?	*L'obiettivo di questa domanda è quello di comprendere come il ruolo/l'entità rappresentata contribuisca all'innovazione della didattica.*	3A
	Rapporti con altri atenei (internazionali)	*Comprendere quale sia il contesto internazionale*	3B
	Che impatto hanno le iniziative? Come vengono misurate?	*Comprendere se ci sono iniziative che mirano in modo attivo a supportare l'innovazione nella didattica e se ci sono modi per misurare l'impatto che hanno*	3C
	Quali iniziative potrebbero essere messe in campo per supportare ulteriormente l'innovazione?	*Obiettivo della domanda è capire se ci sono dei desiderata ancora non attuati o attuabili che contribuirebbero fortemente alla sperimentazione e innovazione nella didattica*	3D

Figure 1. Interview tools used in MIRO

3 RESULTS: EMERGING PATTERN

As presented in the methodology as part of the interview protocol, the interviewee had to discuss various components of the conceptual model used as a framework. The two different sets of actors during the conversation tend to focus on specific components. While professors interviewed for their experimentation at the micro level discussed the activities and their related elements (i.e., material resources, grouping, time and location, assessment). On the other hand, the actors involved at the meso level focus the discussion on the reasons why students learn (e.g., the rationale) and their related objectives.

3.1 Micro level: leverage on students' learning experience to experiment

As emerged as well in the analysis of the survey answers [14] the description of experimental teaching practices has a preponderance of focus on how students learn (code: activities) as a central component in experimentation. Indeed, during the interviews, it appears that often acting on the didactic activities, therefore "changing how students learn," implies leveraging on other components. For instance, introducing peer-to-peer evaluation in a course to change the learning dynamics of the course, it impacts as well on how students are assessed.

"To evaluate their peers, they must know the topics on which they are expressing feedback" [interviewee 2]

Regarding the assessment components, an emerging pattern is experimentation in various forms of peer review or peer assessment [interviewees 2 and 6], where the teacher facilitates the process.

"Building the evaluation form for peer reviews is challenging, but it is the most important thing as you need the most objective parameters to evaluate and how much weight to give to each part to evaluate" [interviewee 2]

Another example of overlap between components is the grouping, which in project-based learning impacts both on how the didactic activity is carried out but as well with whom students learn. Within this area, it emerges that sometimes experimental practices aimed to balance team competencies to create.

"Through a self-assessment of hard and soft skills, we aimed to create groups that theoretically have team members with different strengths" [interviewee 5]

Within this practice, many other elements of experimentation aim to put the students at the center of the learning experience using the constant feedback form to comprehend the understanding of the students and integrate with additional material and resources (i.e., documentary, blogpost) of contents that might be of interest to the students, but that is not in the syllabus of the course. Regarding the components of time and location, although the covid-19 pandemic pushed to reflection on these themes in terms of learning from home and asynchronous, experimental practices also leverage these elements in terms of bringing into the class personal experiences and informal learning. It is the case of an experimental practice [interviewee 6] in which students were asked to keep a diary and report seven cultural events (i.e., exhibitions and concerts) from the design perspective. Finally, another pattern that emerges is the concept that innovation in didactics doesn't come only from implementation of cutting-edge technologies but also from economic choices using the few materials or the classroom arrangement to immerse students in the learning experience. It is the case of interview 1, where interior design students, to learn how the influence of a specific setting might influence interactions, discuss a series of educational materials using the arrangements of the chairs of different parliaments in the world. In this case, the innovation leverages how students comprehend the lessons besides being told during a frontal lecture.

3.2 Meso level: creating the condition to enable experimentation and innovation

During the interviews, it was possible to comprehend the relation within the didactic system taken in the analysis. This context has different actors that serve different purposes:

- The university: which coordinates the various actors and the relation between them.
- The school: which coordinates a set of programs of a specific area of study (i.e., design)
- The department: which coordinates the research over a specific discipline (i.e., design)
- The METID: a unit with the role of researching tools and methods to innovate didactic.

The university has a delegate to the didactic, which has the high-level goal to elaborate strategies to comprehend how students' learning is changing, training teachers and providing them the tools to experiment and develop new spaces for didactic. This actor often has the role of interpreting and anticipating how the rationale and objective components of didactic are changing. Nevertheless, it has as well the role of defining policy and providing infrastructure that incentive the possibility to experiment. It is the case of "Passion in action", an extra-curricular and interdisciplinary activity format that allows teachers and students to experiment. Indeed, students can follow activities that are based on their interests, even if these are not part of the subject of their program. At the same time, teachers have less constraint in defining the didactic activity since it is not curricular [interviewee meso 4]. Regarding the infrastructure, in collaboration with the METID the university developed six classrooms that encourage an active and collaborative approach through technology, furniture, and infrastructure to support the didactic. The School of Design is an intermediate actor between the university and the teachers and defines strategies discipline-related to better comprehend how to facilitate the professors in experimenting. This actor contributes to the reflections with the university on the changes to rationale and objectives components, and given the subject-specific role (i.e., design) it reflects as well on content components. During the pandemic, for instance, the Dean of the school was part of a task force that focused on didactic advocating for the need of design students [interviewee meso 2]. In this regard, on Dean's mandate, a working group foresaw future didactic scenarios for post-pandemic design education contexts [15].

"The role of the Dean is on one side to coordinating the head of the programs, supporting and stimulating the colleagues to bring some sort of innovation to didactic and on the other side confront with the university strategies" [interviewee meso 1]

Within these relations, two other actors support the process; on one side, the Delegate to the didactic of the Design Department aims to harmonize the research process with the didactic ones. On the other side, the university has a unit that studies tools and methods to innovate didactic. The process of harmonization managed by the Delegate to didactic within the Design Department leverages content components, ensuring that the research expertise coincides with the didactic tasks [interviewee meso 5]. The function of the METID concerns mainly components such as activities, materials, and resources. Moreover, working on methods of learning inform components such as assessment, grouping, and time. Lastly, as mentioned before, it studies technologies shaping how a classroom is equipped.

"The aim of the unit is to keep together spaces, methodologies and technologies […] to answer to the challenge of innovating the university didactic" [interviewee meso 3]

4 DISCUSSIONS

The interviewees with lecturers and with the key player in the instructional system allowed the research group to understand the relationship that enable experimentations in didactic to happen and which are emerging pattern of investigation within the studied context. The limits of this study and particularly on the emerging patterns, are linked to the small sample of teaching practices considered; nevertheless, the reflections on the relations between the meso and micro levels are not impacted by the number of interviews. Moreover, the investigative field that is considered focus only one school, this could be

extended in future studies, nevertheless the dimension of the school and its global position across academic ranking create a first exemplary pilot study to further explore.
The analysis of the result provides an empirical confirmation to Van Den Akker ideas that the didactic components are mixed at different levels [11], meaning that each level leverages and influences certain components. Observing the teaching practices taken in exams, the central transversal aspect in the experimentation is a shift in the attention toward students' learning experiences. This shift represents a new role of the teacher, from a traditional position in which one owns the knowledge of the subject to a more modern perspective in which the teacher becomes a facilitator providing a compass to students to navigate within the knowledge and assumes the role of a designer of the didactic activities where students are the central user [16]. It is important to underline that the new role of the teacher is strictly connected with its training as instructional designer [17]. This trend is embodied, for instance, in the emergence of peer review practices or the integration of new materials based on students' feedback. Furthermore, from the second set of interviews emerged the relationship across the didactic system, where the meso level enables the micro level to experiment with various didactic practices inside and outside the curriculum. Marginal to the interviews, it appears that micro and meso levels are limited to a certain extent by a policy defined at the macro level (i.e., state policies). Therefore, many experimentations of didactics are developed through extra-curricular activities, nudged, and supported by several actors.

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USING MULTI-LEVEL PROTOTYPING TO SHOWCASE STUDENT MOBILITY DESIGN CONCEPTS IN URBAN CONTEXTS

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ABSTRACT
The emergence of new vehicle designs that fall outside the traditional urban mobility ecosystem, and recent paradigm-changing approaches to street layout design, require input from both urbanists and designers of mobility solutions. However, vehicle design concept showcases in academia have traditionally been vehicle-centric, using 2D materials and prototypes at the physical level (low-fidelity or small-scale) with little to no representation of the urban context. The emerging use of prototypes at the immersive level (AR/VR) in conjunction to the traditional materials provides an opportunity to represent both the vehicle and the urban context at full-scale, facilitating the input of urbanists as showcase participants. In this paper we provide a brief account of the use of prototypes in the discipline of mobility design at different levels (physical and immersive) and at varying degrees of fidelity, as well as prior work integrating the different prototyping levels. We then use a case study to propose our own multi-level prototyping approach for final showcases to present vehicle concepts.

Keywords: Future mobility design, virtual reality, augmented reality, immersive technologies, urban planning, transportation design, automotive design, vehicle design

1 INTRODUCTION
For decades, stable street layouts and vehicle ecosystems permitted urbanists and vehicle designers (also referred as automotive, transportation, and in this paper mobility designers) to work independently from one-another. However, with street layouts transitioning to multi-modality and new types of vehicles appearing on the mobility ecosystem [1], urbanists and mobility designers need new tools that facilitate their multidisciplinary collaboration. To this aim, we propose augmenting the final design showcases of mobility design projects in academia to show the integration of new vehicles with the urban context.
In academia, showcasing final mobility designs has traditionally been vehicle-centric, using 2D representations and 3D physical prototypes to explain the vehicle. The audience (usually other mobility designers) provides vehicle-centric feedback. Now that both the urban environment and the vehicle need to be in the equation, it becomes crucial to add urbanists. However, representing that scenario in 2D is inaccurate (off scale) or impractical if using 3D physical prototypes. An emerging solution in the field of mobility design education is immersion using Virtual Reality (VR) prototypes [2]. Immersion permits experiencing and interacting with both the vehicle and the city in full-scale. Additionally, Augmented Reality (AR) can serve as a bridge between the virtual and physical worlds by overlaying virtual geometry over physical prototypes without losing sight of other attendees and the showcase environment.
In this paper, the background (section 2) first addresses the changing urban fabric and new vehicle paradigms that make the enhancement of final mobility design showcases relevant to better include urbanists. Second, we present an overview of prototypes, their objectives, their physical and virtual levels, and their degrees of fidelity. Third, we address their use in the field of mobility design. Fourth, we discuss previous approaches that use a hybridization of immersive and physical prototypes for the industrial design process and present the research gap regarding the specific application to the field of mobility design. We follow up with the methodology (section 3) used to develop a multi-level prototype experience that allows mobility designers to showcase their vehicle solutions integrated to the urban

context, enabling a seamless discussion with urbanists. We also present a case study of the final showcase of a Future Mobility Design undergraduate studio about micro mobility and its integrations with the urban environment, including the testimony of stakeholders in the AR/VR and urban development industries who experienced the multi-level prototype in the showcase. (Section 4) outlines the impact and limitations of our work and future research opportunities.

2 BACKGROUNDS

2.1 The changing urban fabric and new vehicle paradigms

For the past century, cities have been designed with a car-centric approach, producing barely unchanging street layouts with a stable vehicle ecosystem (e.g., cars, trucks, motorcycles, bicycles) [3], permitting mobility designers and urbanists to work separately. However, as trends in city design transition from car-centricity into multi-modality [4], mobility designers are producing new category-defying vehicle designs which are at a risk of not being considered when creating the streets of the future. One example is the emergence of micro mobiles, [5], which are slower and lighter than cars but need different considerations to bicycles (e.g., e-scooters and hoverboards). Such vehicles have and continue to emerge in such a variety that makes it difficult to define what a 'micro mobile' is [5], presenting challenges in the creation of street design parameters [6]. Thus, it is important to create tools for urbanists and mobility designers to work together.

2.2 Prototypes at different degrees of fidelity, and at the physical and virtual levels

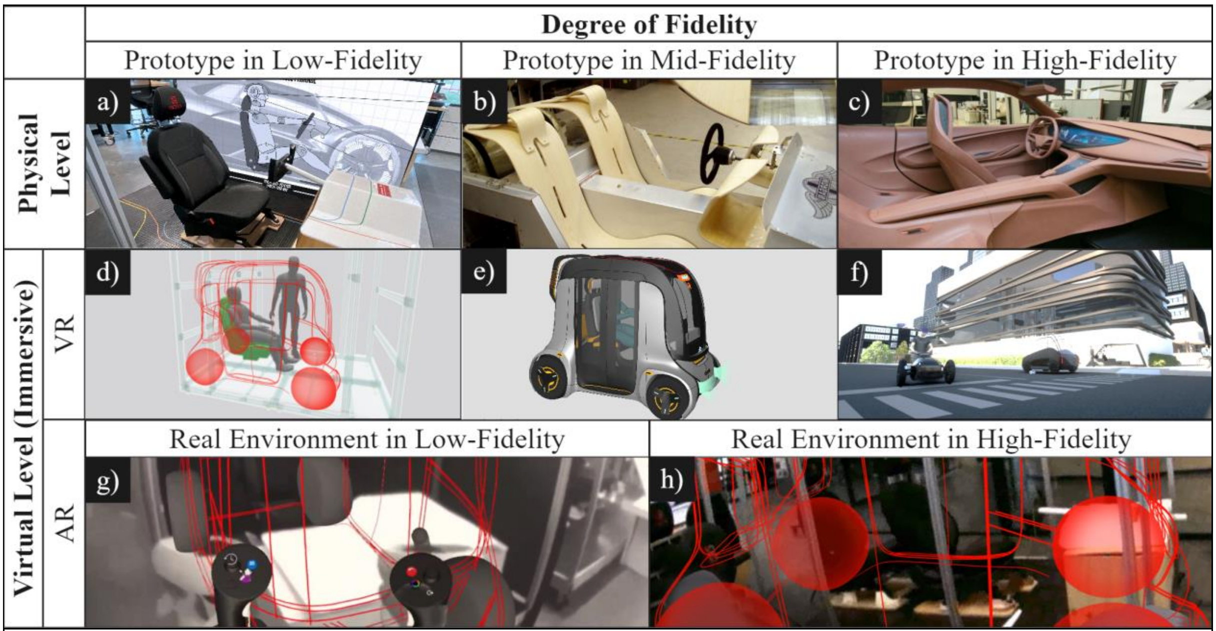
Together with 2D representations (e.g., sketches, renderings, 3D CAD geometry displayed on 2D screens, etc.), 3D representations (e.g., physical mock-ups, CAD models experienced immersively) are part of the representational ecosystem used throughout the design process [7]. We refer to these 3D representations as prototypes, which are preliminary versions of a design that can display its aesthetics and/or function [8] as well as its user interaction and experience. Diverse types of prototypes aid the designer in decision-making at different points of the design process [9]. Of the existing roles of prototypes in literature, two stand out as pertinent for this work: 1) Learning prototypes, used to advance design concepts in development, and 2) Communication prototypes, which represent more developed designs, [8], such as those in final showcases. Thus, the degree of fidelity of the represented design progressively increases as the final design is achieved. Prototypes also have varying degrees of fidelity due to the dimensions of the design object, using small-scale models when fully sized ones become too resource-consuming to construct in high fidelity. While small-scale physical models provide a collective viewpoint for showcase viewers, they do not provide a first-person experience of the design concept.

Virtual geometry in any degree of fidelity has no digital scale limitations but it does not provide a first-person experience while seen behind a 2D screen or image. Thus, virtual reality (immersion) becomes necessary. This can be achieved with projection display systems (e.g., CAVE [10] and Hyve 3D [7]) or with head-mounted displays (e.g., Meta Quest 2, HTC Vive). While projection systems are highly effective for co-located multi-user experiences such as final design showcases, they require specialized equipment installed on-site. Head-mounted displays require little to no extra equipment. However, by being worn on the face, they produce interaction challenges for co-located viewers. Using them for final showcases requires preparation, as untrained individuals will need time to dominate actions such as changing viewing angles, scales, or rotating a virtual object. For showcase attendees to master these basic actions, a training session of about 30 minutes is recommended, although this extra time will not always be available. Moreover, full immersion means the virtual and the physical world do not correspond, and multiple co-located users cannot see each other which can be disorienting. Nonetheless, the recent introduction of in-app passthrough viewing to the Meta Quest 2 turns the headsets into AR tools, bridging the virtual and physical experience by overlaying virtual geometry on a black and white low-fidelity camera-generated reproduction of the real environment.

2.3 Use of prototypes in mobility design showcases

In academia, traditional final mobility design showcases involve a verbal presentation while audiences (usually other designer members of the community of practice) [11] play a spectator role who provide vehicle-centric feedback at the end of the presentation. These academic showcase events include 2D materials such as posters and/or images/animations projected on screens, and physical communication prototypes. Creating high-fidelity (high-fi) full-scale models is reserved for industry practice and not viable in academia. Adding the urban context would make full-scale even more impractical. Thus, final showcases in academia traditionally use high-fi small-scale physical prototypes, with full-scale low-fidelity (low-fi) prototypes appearing less frequently.

High-fi and full-scale virtual representations have been used in industry for decades. In the 2000s, large retro-projected 2D displays representing vehicles in 1:1 scale were introduced (e.g., Powerwalls) [12]. However, the vehicles could only be seen at a distance (a limited first-person experience). Today, the emerging use of VR/AR prototypes provides the required upgrade. Figure 1 shows the use of learning and communication prototypes for vehicle design. They allow audiences to transition from spectators to active participants, capable of experiencing aspects of the concept such as materiality, user-interactions, and the urban context. However, 2D material and physical prototypes, even if small in scale or fidelity are often preferred by showcase participants over VR [13], even when its benefits are lost. As stated in section 2.2, using AR bridges low-fi full-scale physical prototypes with higher fidelity virtual geometry, allowing for mobility designers to display vehicle solutions in the urban environment in a more seamless transition between both disciplines.



Prototyping methods and degrees of fidelity		
a) Low-fi physical communication prototype (from academia): A rough mock-up blocking out essential design elements.	**b) Mid-fi physical communication prototype (from industry):** A more developed mock-up, partially showcasing the design concept.	**c) High-fi communication prototype (from industry):** The design concept’s function and aesthetics are fully represented.
d) Low-fi VR communication prototype (from academia): A rough line drawing model showing essential design elements.	**e) Mid-fi VR communication prototype (from academia): A** more detailed model showing touch points and surfaces.	**f) High-fi VR communication prototype (from academia): A** finished model and context environment shown in high quality.
g) Low-fi Real Environment: Black and White cameras from VR headset used to overlay VR content on real environment.	**h) High-fi Real Environment: Full** HD colour cameras from VR headset used to overlay VR content on real environment.	

Figure 1. Prototyping levels and degrees of fidelity used in academic final mobility design showcases

2.4 Prior work integrating immersive and physical prototyping

Prior integrations of physical and virtual prototyping levels including AR and VR have been proposed for both the development and final showcases of design concepts. One uses the term “virtuality continuum” to explain the different degrees of integration between the real and virtual environments [14]. Another is the hybrid representational ecosystem [7], which intends to facilitate multi-user co-creation between the project stakeholders. Also, tangible virtual reality (TVR) is proposed as a 1:1 scale combination of VR/AR furniture models with key physical touch points to provide a first-person virtual and haptic experience [13]. However, none of them combine the attributes of multi-level prototyping using head-mounted displays for viewing VR-generated geometry while integrating AR capabilities alongside 1:1 scale physical prototypes, to meet the specific constraints of mobility design in academia which include: **1)** shorter timelines (academic semesters) than those of industry, **2)** the required degrees of fidelity at the physical and immersive levels (AR /VR), **3)** a first-person experience of the vehicle concept and its urban context, for final showcase participants to give feedback.

3 USING MULTI-LEVEL PROTOTYPING TO SHOWCASE STUDENT MOBILITY DESIGN CONCEPTS IN URBAN CONTEXTS

3.1 Research context

The multi-level prototyping method we propose was developed at the University of Cincinnati between 2016-2023 and the University of Montréal between 2021-2023. The methodology was refined in 23, 15 week-long undergraduate level projects ranging from 8 to 24 students. Each project is divided into three phases of 5 weeks each: 1) research and VR proficiency development, 2) ideation and selection of design direction, and 3) execution and showcase of final design. Every project was done with industry partners, either in full collaboration or with their feedback (e.g., General Motors, Stellantis, BRP), as well as urban planning organizations such as Uptown Consortium, and consultants in the city of Cincinnati. From a mobility design studio project, we have selected one key student's final design showcase to illustrate the outcomes pertaining to the proposed multi-level prototyping methodology. Conclusions are based on the testimony of AR/VR experts and urban planning stakeholders who attended the event.

3.2 Multi-level prototyping proposal

With the main goal to allow participants to experience the functional and aesthetic elements of the mobility design concept in its urban context, Figure 2 shows the proposed multi-level prototyping methodology consisting of **1)** 1:1 scale Low-fi physical communication prototype made of easily modifiable materials such as cardboard, tape, and foam core, to provide tangible touch points, haptics, and ergonomics, **2)** Low-fi black and white AR from the VR headset to create a seamless bridge between the physical and VR prototype without disorientation while keeping other showcase attendees visible, and **3)** Mid-fi VR scene of the final vehicle and surrounding urban environment shown in 1:1 scale (simple materials and environment lighting) correlated with the touchpoints of the physical prototype, while virtual geometry shows the aesthetics, materiality, and interactivity of the vehicle. Participants are situated on or around the vehicle's physical prototype while having a VR overlay that matches the physical footprint and seamlessly walking or moving around the scene using AR. They can also take a spectator role and watch a traditional screen which shows the content from within VR.

Figure 2. Multi-Level Prototyping in academic final mobility design showcases

3.3 Multi-level prototyping Case Study approach for final design mobility showcases

The following is a case study from an undergraduate micro mobility design studio in the Summer of 2022, consisting of 4 groups of 5 third-year Industrial Design students. Groups proposed concepts for micro mobility hubs with each student designing one of the following: micro mobiles, stations, hubs, urban context, kiosks, UX/UI, or CMF. The final showcase was held in an open lobby space where each group had large posters with their research, ideation, and final designs. They also had large screens displaying the final VR experience of their urban hub. Chosen students included a multi-level prototype consisting of **a)** low-fi physical vehicle prototypes, **b)** VR Gravity Sketch models of the vehicle's exterior, interior, and surrounding urban environment, **c)** AR enabled features through the VR headsets, and a laptop projecting the VR experience for audience members not wearing headsets (Figure 3).

The following testimonies were documented after the event took place and offer experts' opinions on the relevance and impact of multi-level prototyping in mobility design showcases related to the urban planning context and AR/VR industries. From the urban planning context, the interviewed expert comments that the methods used to showcase the experience were highly persuasive and efficient. VR can be intimidating for non-expert users but using the headset cameras made it more intuitive to sit down on the physical prototype to experience the vehicle concept and surroundings. These methods can help in the communication process between different audiences. Additionally, they highlighted not just seeing the vehicle and its experience (representing the human scale) but understanding the relationship to the urban environment (macro scale). Urban planners also said that these technologies will be crucial to validate the design process of future streets and their components (vehicles, pedestrians, cyclists, public transit, stations, among others), especially since city planning must change as new types of vehicles arise. The interviewed AR/VR expert mentioned that the combination of low-fi physical, low-fi AR, and mid-fi VR created a compelling experience for audience members, allowing full immersion to the design without any disconnection to the physical environment. The AR/VR expert reported that the multi-level prototyping approach felt appropriate, since it considered the scope of the student projects while maximising their impact to a wide variety of guests invited to the final showcase.

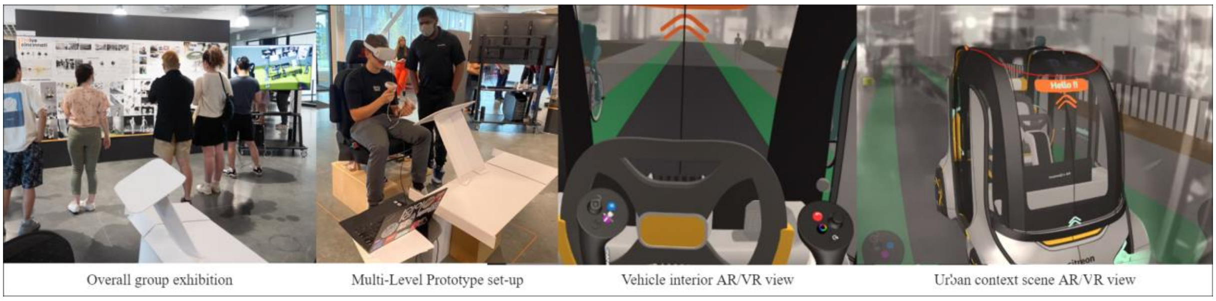


Figure 3. Chosen student's micro mobility concept shown in the final showcase

4 DISCUSSION AND CONCLUSION

Emerging vehicle types and changes in street layouts validate the need for creating compelling methods to connect mobility designers and urbanists. The case study presented in this paper shows how the emergence of immersive prototyping can bridge both disciplines by adding the representation of the vehicle in the urban context at full-scale to final mobility design showcases. The two key contributions proposed in this paper are: **1)** A brief account and evolution of prototyping methods for design, focusing mostly on emerging AR/VR/TVR and the representational ecosystem. **2)** The proposal of a replicable VR headset-based multi-level prototype approach for final showcases of student mobility design projects. This approach contextualizes showcase participants on both the human scale of mobility design and the macro scale of urbanism, which permits the immersive representations of both the urban context and the designed vehicle (mid-fi geometry), its ergonomic and functional touchpoints (low-fi physical mock-up), while maintaining the visibility of the real environment through AR (low-fi visualization). The use of multi-level prototypes as presented in this paper enables multidisciplinary audiences (like urbanists) to provide more comprehensive feedback than with traditional methods (posters, slideshow displays, and animations), which should continue as complimentary elements in the showcase.

Three kinds of limitations arise: **1)** The virtual geometry as proposed is static (not interactive). VR simulations using video game engines are required for more complex interactions. **2)** The democratized use of AR/VR in the field of mobility design is in its infancy, which brings two problems: there are still alignment issues when matching the virtual and physical environments, and the AR feature is in low-fi (black/white, low-res). However, newer generations of VR headsets such as the Oculus Quest Pro present a higher-fi AR representation of the physical environment and applications such as Gravity Sketch have recently begun offering tools to anchor it to the virtual one. **3)** The use of VR headsets presents some inconveniences. Among them, the learning curve for final showcase guests to use the technology smoothly, which could be reduced by having a short training session before the event whenever possible. Another inconvenience is the lack of VR headset availability for all audience members, or attendees who decline to use them. Projecting the VR/AR experience on a screen can be an alternative that provides access for these participants.

Given the proposed methodology and comments from interviewed experts, future work could focus on three areas: **1)** The development of multi-located (in-person and remote) showcase experiences. First, by having remote attendees join the VR portion of the environment while the in-person showcase happens, and second, by recreating the physical mock-up in a different location and synchronously have all attendees join the same multi-level prototype experience. **2)** The constant emergence of new VR features and applications to the field of mobility design in academia pose two paths to enhance final design showcases. The first is that haptic technologies offer a closer link between the physical prototype and virtual geometry. The second is that the learning curve for video game engines is being reduced, making it more viable to add interactions to the showcase during the time constraints of academic terms. **3)** More importantly, future work can focus on further bridging mobility designers and urbanists by including these last ones during a multi-disciplinary design process rather than only at the final showcase.

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PROBLEM BASED LEARNING THROUGH DESIGN THINKING TO STRENGTHEN EDUCATION IN SOUTH ASIA

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ABSTRACT
The practice of finding and solving ‘wicked’ problems, i.e., real-world, complex, and uncertain; creatively, so as to have a positive social impact has always been a designer-ly pursuit, and Problem based Learning (PBL) is a known to be an approach that enables real world problem solving, apart from other top skills for the future, as reported by the World Economic Forum (2016).
Based on the empirical findings, from several case studies and workshops, it was found that South Asian universities require resources that help in practical implementation of PBL approach in undergraduate engineering education, that is otherwise common practice in design discipline. Thus, a collated view of the PBL process, with stages, defined roles, and general guidelines for problem formulation is compiled for handy reference. This paper also presents a literature review on the historical development of PBL pedagogy; its definitions, characteristics and learning approaches; comparison with other approaches, such as, project-based and case-based, and its effectiveness in terms of measures and metrics; and discusses the classification of ‘problems’, its types and attributes, and the importance of identification and formulation of the ‘right’ problem to have the right impact with respect to Sustainable Development Goals. The key contribution of this paper is to showcase how Design Thinking has been used as a strategy to inculcate Problem-based Learning (PBL) into undergraduate engineering education and present the implementation of PBL and its impact on engineering education in South Asia .

Keywords: Problem based learning, design thinking, education

1 INTRODUCTION
Problem-based learning (PBL) is an “instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem”, in which students learn through “facilitated problem solving that centres on a complex problem that does not have a single correct answer”(Savery, 1999; Torp and Sage, 2002; Hmelo-Silver, 2004). Literature reports that it has profound implications on the motivations of the student to learn, and can be widely used to support several domains, as it is known to help develop various top skills, such as, critical thinking, complex problem- solving, self-learning, collaboration and communication skills (Duch, Groh and Allen, 2001) necessary for young graduates to be industry-ready and responsible innovators.
Technical education offered by South Asian Universities, particularly at undergraduate level, remains didactic, teacher-centric and contextually disconnected from the issues and challenges of the region, in turn, making the fresh graduates poor in skills needed to be industry-ready. In addition, the members of faculty too, struggle with inculcating real-world issues and problems into practical experiences for students due to course loads, lesson plans and lack of training in more appropriate pedagogical approaches (Acharya et al.., 2021). Problem based Learning (PBL) is one such approach, and has been reported to develop various top skills, as identified by the World Economic Forum (2016). The limitations reported in global context are applicable to the South Asian engineering education as well. The problems of students not being employable at the end of the course is a major issue as highlighted by various forums. Issues of rote learning, insufficient exposure to real-life problems, the development of soft-skills and the exposure to larger contexts is present in the South Asian context as well. Further,

the focus on examination and grades, rather than on learning, is a major concern for this part of the world. This is compounded by the fact that in countries like India, the majority of employers for engineering graduates are in IT and services sector across various streams of engineering, thus leading to the questions among students the usefulness of core engineering courses as compared to industry ready courses. The employability of students is a huge concern. This has led to a phenomenon in the industry where the companies recruit the graduates based on their general aptitude rather than industry ready skill sets and subject them to an extended training programme which span more than a year in some cases. This shows the lack of confidence of the industry in direct deployment of students in the industry without making them ready in such prolonged training exercises.

Through the Erasmus+ funded Capacity Building in Higher Education (CBHE) endeavour, a three pronged approach was taken : (i) development of a handy PBL best-practices quick guide compilation, (ii) hands-on inculcation of these best practices through case studies and workshops.

2 DEVELOPMENTS OF A HANDY PBL BEST PRACTICES QUICK GUIDE

Problem Based Learning (PBL) is an innovative teaching method, derived from the theory that, learning is a process in which the leaner actively construct knowledge (Gijselaers, 1996). PBL best practices were identified and contextually compiled, so as to enable the faculty in educating future problem solvers, with the below summarised topics.

2.1 Definitions, Characteristics and Learning Principles

Barrows (1996) identified six core characteristics of PBL, explained as follows: Learning is student-centred; Learning occurs in small student groups; Teachers are facilitators or guides; Problems form the organizing focus and stimulus for learning; Problems are a vehicle for the development of problem-solving skills; and New information is acquired through self-directed learning.

PBL is an approach to learning which is well matched with prescribed principles of cognitive and constructivist theories of learning. PBL process promotes the activation of prior knowledge and its elaboration. Also, discussion of a relevant problem in a small group facilitates processing of new information. This problem-oriented study allows mastery of principles and concepts such that that can be transferred to solve new problems. Solving problems via PBL method enhance integration of different subject/ domain knowledge. Also, PBL makes learning intrinsically interested and keep students self-engaged in learning. These propositions underlying PBL have been validated and have empirical basis (Schmidt et.al. 2011, Schmidt, 1993; Norman et.al., 1992).

2.2 Effectiveness of PBL Approach : Measures and Metrices

Earlier studies revealed that the 'level of knowledge tested', as a learning outcome, was found to be equivalent to that of traditional approaches, however, students who experienced PBL showed; (i) improvement in problem-solving skills (Albanese and Mitchell, 1993; Vernon and Blake,1993) and (ii) increased engagement and motivation to learn, as they preferred PBL to the traditional methods of teaching (Denton, Adams, Blatt, & Lorish, 2000; Torp & Sage, 2002).

Dolomons et.al. (2016) study, across curriculum-wide PBL implementation and single-course PBL implementation, noted similar findings to the earlier studies, where PBL has profound implications on the motivations of the student to learn, stating that "the freedom to select their (students) own resources to answer the learning issues, which gives them ownership over their learning", and has capability to foster deep learning. Thus, the onus falls on the shoulders of the students as peer teacher (Caswell, 2017) to ensure the motivation of the team is maintained. Several studies in engineering provide empirical support that students learning gains for conceptual understanding is higher than traditional lectures (Yadav, 2011). PBL approach offers the opportunity for students to enhance their critical thinking and self-directed learning skills, and engages students in solving problems (Williams,1999). Students' perceptions that the curriculum encouraged critical thinking significantly increased after PBL curriculum was conducted (Birgegard, 1998). Students' critical thinking skills are fostered through their group discussions (Rideout and Carpio, 2001). s suggested that PBL encouraged them to share their opinions with others, analyse situations in different ways and think of more possibilities for solving problems.

Skills like Critical Thinking can be evaluated using California Critical Thinking Skills Test CCTST, Motivation and engagement of students can be evaluated using Motivated Strategies for Learning Questionnaire (MSLQ) Manual (Pintrich, 1991), effectiveness of group activities and interpersonal skills, i.e., Collaboration, can be evaluated with Team Assessment Tool (Moore et.al. 2006), while Problem-solving and communication skills maybe assessed (summative) by peer, mentor and expert/jury across the duration of the course or curriculum.

2.3 PBL Process

There are many variants of PBL as it can be moulded according to institute traditions and individual course requirements, however, it is described in brief as follows; *The process starts with an ill-defined, real life problem formulated by tutor/ teacher. Students in a small group starts analysing the problem systematically. The terms and concepts are understood and clarified first. Students in a group have agreed opinion on meaning of the problem. Then, students construct a tentative theory explaining the phenomena or events described in the problem-at-hand in terms of its underlying principles or mechanisms. Students then identify the facts that they already know and what they require to know in order to solve the problem. Learning issues for individual study are formulated. These learning issues usually consist of questions arising from the discussion. Students search and evaluate resources which can be useful to learn problem domain. Students pursue learning issues through individual, self-directed learning usually using a variety of resources: books, articles, movies, and Internet sites where, tutor scaffolding takes place. Students return to their tutorial group, review and share what they have learned, propose the solution and elaborate different aspects of it. Explore to what extent the students' understanding of the problem has developed and whether misconceptions remain that need to be addressed. Students self-evaluate and evaluate others in the group (peer evaluation).*

2.4 Role of Tutor /Mentor in PBL

Traditionally, teachers have been teaching the concepts as well as applications of the concept whereas PBL methodology asks teachers to be facilitator and help students to manage metacognitive activities. Thus, adopting PBL is difficult for teachers as they must transform the whole methodology that they have been following for years. Being a mentor, faculty has to keep in mind that learning is a constructive, not receptive process. They need to permit students to discuss issues. They need to ensure that learning issues are raised and discussed. Being a tutor, faculty should not stifle students' discussion by giving mini-lectures or factual information, asking stream of questions, giving answers or telling students whether they are right or wrong in their thinking, telling students what they ought to study or read, etc.

2.5 Importance of 'right' problem : Types and Attributes

Chi & Glaser (1985) defined problem as a situation in which one is trying to reach some goal and must find a means for getting there. In design domain, it is observed that problem-finding is as important at problem-solving and requirement identification, i.e., "right problem", is critical for seeking appropriate and satisfactory solution. However, in existing PBL approaches, a problem is defined, though ill and often complex; whilst leaving the activity of problem solving open-ended and the expected solution. This raises serious reservations on the 'self-learning' process of undergraduate students in technical schools across South Asia as course syllabus is heavy and didactic, which may inadvertently demotivate the students and they aren't naturally inclined to question. An exposure to design thinking; i.e., problem-finding and problem-solving, showed potential in imbibing reasoning, questioning, curiosity, and drive the students to pursue a valuable problem, with motivation and purpose and in turn, motivate the inculcation of PBL into engineering courses [1,2].

Jonnassen (2000) classified the problems into various types (i.e., logical problems, algorithms, story problems, rule-using problem, decision-making problems, troubleshooting problems, diagnosis-solution problems, strategic performance, situated case analysis problems, design problems, dilemmas). On one hand, story problems and algorithms are typical classroom problems that are well structured, procedural and predictable in nature. On the other hand, design problems and situated case analysis problems are real-world, ill-structured problems. Shin et al (2003) discovered that solving well-structured and ill-structured problem needs different mental skills. This shows that the performance of classroom problem-solving skills is independent and learning of which does not necessarily help to solve practical real-life problems. Real-life problems are ill-structured and complex. Problem complexity is defined by the number of issues, functions, or variables involved in the problem; the degree of connectivity among those properties; the type of functional relationships among those properties; and the stability among the properties of the problem over time (Funke, 1991).

Delisle (1997) prescribed the general guidelines for problem statement formulation in the form of checklist. Marchais (1999) identified criteria for constructing problem and subsequently evaluating them. (e.g., Stimulating thinking, analysis, and reasoning, assuring self-directed learning, using previous basic knowledge, proposing a realistic context, leading to the discovery of learning objectives, arousing curiosity etc.). Gijselaers (1996) identified the features of problem that make PBL ineffective, (i.e., description of problem has questions which are substituted for students generated learning issues, title of problem is same as title of the book chapter, problem is too simple (well- structured/ having only one acceptable solutions) which can be completely resolved during initial analytic process).

2.6 Defining the 'right' problem

Halfin (1973) identified total 17 mental process used by practitioners, as follows ; defining the problem or opportunity operationally, observing, analysing, visualizing, computing, communicating, measuring, predicting, questioning and hypothesizing, interpreting data, constructing model and prototypes, experimenting, testing, designing, modelling, creating and managing. Here Haflin refers to 'designing' as an activity or task, while latter literature clarifies that, "*Design is a type of problem solving in which the problem solver views the problem or acts as though there is some ill-defined-ness in the goals, initial conditions or allowable transformations*" (Thomas and Carroll, 1978). Cross (2001) describes designing as, 'finding' appropriate problems, as well as 'solving' them, and stressed that it includes substantial activity in problem structuring and formulating, rather than merely accepting the 'problem as given', and further adds that, designers' behavior is characterized by their treating the given problems as 'ill-defined', for example, through exploration where goals and constraints are changed even when they could have been treated as well-defined problems.

Awang and Ramly (2008) used creative thinking approach, a sub-set of Design Thinking with focus only on 'problem-solving', for implementing PBL in the classroom and found that the combination of both enhanced creative skills and technical abilities. Thereby suggesting complementarity between the PBL methodology and the methods of design practitioners, i.e., Design Thinking.

Williams & Williams (1994) reported the similarities between PBL and design process, i.e., large no. of stages, identification of problem as an opening phase, require motivation, organization skills and capability to initiate things, open-endedness to outcomes, group work and collaboration. While PBL is an instructional, curricular approach where the problem is defined and given with the intent to stimulate learning, Design is a cognitive process of 'finding' an appropriate, 'ill-defined' problem. Thus, supporting students to identify contextually grounded 'real life problems' and accordingly seek solutions, enables them to go beyond Remember-Understand - Apply, towards Analyse-Evaluate-Create, hierarchically identified by Bloom's Taxonomy (1956) as key learning objectives, and further enhances their ability to contribute to society.

3 IMPLEMENTATION AND IMPACT

3.1 Implementation

The two key modalities for implementation and dissemination were ;

(i) Case-study based workshop, with 70 case participants undertaking PBL through real world cases [2]. The case participants consisted of students from European and Indian universities who largely had prior exposure to PBL based curriculum, and faculty from Nepal and Bhutan, in mixed teams so that the knowledge transfer to the South Asian HEIs would happen at faculty as well as student levels. 7 cases were identified with expert-mentors, and each team comprised of 6-8 members with diversified backgrounds in terms of its composition: across ages, skill sets, hierarchies, roles in their home institution and also project, disciplines, cultures and so on, to imbibe multi-disciplinary mindset. Teams went through an extensive series of lectures and workshops primarily focused on design thinking and PBL methods and worked for two weeks to discover socially acceptable and sustainable solutions to problems they identified with the help of given brief. During this journey, they were facilitated to interact with the social communities, formal organizations and NGOs for having a broad understanding about the problem and various stakeholders involved. In the concluding session of the workshop, each team presented the solutions developed by them, and took a self-assessment on the learning outcomes and experiences.

(ii) Curriculum design workshop, where capacity building of 30 South Asian faculty members is undertaken through re-designing existing engineering courses, under mentorship [1]. Its main objective was to apply 'design thinking' strategies to collaboratively design the curricula suitable for each of the beneficiary HEIs, across disciplines, in Nepal and Bhutan. The European and Indian institutions presented on their know-how in the area of PBL, and faculty and research associates mentored sessions to co-create courses, while considering the contextual and practical issues of affiliation, evaluation, etc.

3.2 Findings and Insights

The key findings from (i) are ;

- **Faculty from being teacher in a course to a mentor in a PBL based curriculum -** The transformation of faculty from teachers to mentors was appreciated as the most significant factor in terms of shifting to a PBL based curriculum. As discussed in the earlier sections, the mentor's role is quite different from that of a teacher. The hands-off approach where the students are allowed to freely discuss the issues with minimal intervention and direction by the mentor is the key to self-learning. However, it is a difficult role as the mentor still has to balance the learning objectives of course while allowing students to explore freely and define their problems/spheres of work.
- **Upfront uncertainty in goal setting may not be comfortable to students -** The faculty from Nepal and Bhutan, who transformed themselves as students for this workshop, faced uncertainty in the early stages of the case-study where the goals are not defined, and the problem is ill-structured. The mentors' major role is to keep the morale and motivation of the team going so as to meaningfully achieve the learning objectives and still expose students to the uncertain nature of the problem definition in real world. Tools to get constant feedback from the students, especially like a mood meter, is essential to understand the team spirit to create quality problems.
- **Appreciation of learning objectives is a natural outcome of PBL process -** The students (including the teachers from Nepal and Bhutan) acknowledged the effectiveness in PBL based methodology in appreciation of the learning outcomes. The case studies made the teams contact local communities and interact with NGOs and various other entities on the field, which led to sometimes a drastic change in objectives. The interactions also helped dispel some of the initial notions and biases that existed in the team. The teams were naturally passionate about their solutions by the end of the case study exercises and owned their work.

Some key points raised and addressed during the (ii) are ;

- PBL is best suited for courses with a practical or project component, which are usually at the end of the programme in fourth year projects for undergraduate students.
- PBL has been adopted with some success in core engineering courses as well. Some experience in this regard was shared by a few partnering HEIs.
- The scoring schemes should reflect the work done throughout the project and have weightage for even failed prototypes etc.
- PBL is excellent method especially if the course involves teams working on inter-disciplinary areas.
- The number of students registered should not have a bearing on the pedagogy. PBL has been shown to be adopted on class sizes of more than 100 as well. However, as the class size increases, there is a need for specific mentors for teams which are usually about 5-6 students strong. Thus, there is a need for strong mentors as day-to-day facilitators and an overall course instructor who guides the philosophy of the course. For smaller number of students, the faculty can double as mentors for the teams.
- A lot of discussion on the course evaluation is necessary to capture the assessment in line with course objectives. Usually, a combination of continuous evaluation throughout the course study with a final assessment based on one or a combination of presentations, peer evaluations, prototype fairs and presentations to the community would be warranted in the case of a PBL based course.
- A template was designed for the HEIs to structure their new course adoption under the PBL mode. The template is given later in this document.

4 CONCLUSIONS

Newly initiated PBL practitioners, as seen in South Asian universities, require theoretical and practical hand holding in the early implementation of PBL courses which are known to imbibe industry-ready skills into engineering and technical curriculum. As a result, a handy reference guide of 'best practices' as pedagogical aid, along with workshops and multi-disciplinary groups immersed in PBL case studies was found to be a successful strategy to inculcate Problem-based Learning (PBL) into undergraduate educational practices and content. Following these efforts, the beneficiary universities have been in turn, practicing PBL cases in their regular engineering courses, that were developed during the workshops and have been referring to the handy guide, stating that it is of great value and usefulness. Future works entail the evaluation of its effectiveness in inculcating PBL into Engineering education.

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COMPETENT DESIGNERS: INCULCATING DESIGN COMPETENCIES THROUGH COURSES

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ABSTRACT
This paper presents the use of the Design Competency Assessment (DesCA) framework to enhance collaboration between courses in an interdisciplinary design-based curriculum at the Singapore University of Technology and Design (SUTD). The paper illustrates the use of this framework in SUTD’s second term Design Thinking Project (DTP). The DTP explicitly brings together the learnings of the courses taking place in that term, in particular the introductory Design Thinking and Innovation (DTI) course. DTP as a joint project is facilitated by faculty from different disciplines. Students have to demonstrate how different disciplines have influenced their design project. DesCA was introduced in the planning of the project to identify competencies needed for DTP and overlay these onto the existing course schedule. The results of this case study suggests that DesCA, as a competency-based approach, provides a common language between faculty of different disciplines and is an effective means: to gain a common understanding of the required competencies; to obtain coherence between courses in an interdisciplinary curriculum; and to form the basis for assessment. This should allow for a more coherent and integrated approach to design education, which is essential for producing graduates with a broad range of knowledge and skills and attitudes to tackle complex global challenges.

Keywords: Design education, engineering education, competency-based education

1 INTRODUCTION
Most educational programs follow a set schedule with semesters or terms. To graduate, students must complete a specific number of courses or credits [1]. Curricula are subject matter oriented and “are divided into courses on specific areas of expertise, often the result of a combination of historical factors (this was the way I learned it), a clinical analysis of the so-called structure of a domain or discipline (this is the ‘objective’ hierarchy of the subject matter), and analysis of the expertise of the teachers (Professor X is an expert in…)” [2]. However, the traditional view of knowledge as discipline-based has evolved to include an integrated understanding of education where the primary goal is not limited to knowledge acquisition but also knowledge application [3] and generation [4]. As the complexity of global challenges increases [5], students recognize the need to have a broad range of knowledge and skills to offer value to future employers [6]. The discipline of design challenges current thinking, adopting creative methodologies and practices to frame problems and offer solutions [4]. The integration of design thinking methodologies into a wide variety of curricula has highlighted the potential of creative processes and aided in the development of innovative solutions in various fields [7]. “Design thinking, combined with scientific and technological thinking, allows us to explore the new frontier of design and innovation and to link design to the future” [8].
Although efforts have been made to integrate design into the overall curriculum [9–11], design is still largely present as a distinct and separate subject and its “integration with other subjects is often left to the students” [12]. Interdisciplinary and multidisciplinary formats of design education offer promising approaches to provide students with opportunities to learn by seeking and integrating knowledge from multiple disciplines in contexts of varying complexity [13]. The Singapore University of Technology and Design (SUTD) has been recognized as one of the top emerging engineering schools in the world [14] and it prides itself on fostering technically proficient leaders and innovators through its distinctive interdisciplinary design-based curricula [15][16]. Nevertheless, challenges remain in implementing design throughout the curricula, such as the difficulty to maintain coherence between the design

competencies taught in the various courses, the lack of clear progression pathways towards design competency, and the resulting struggle of students to comprehend the design process as a generic approach and identify their learnings and progression. Since SUTD expects design to be present in each course regardless of major or discipline a further challenge is the limited background in design methods and approaches among most of the faculty: they are expected to be involved in core design courses and incorporate design components in their own courses to teach and assess discipline-specific concepts. Nilsson et. al [17] pointed out that one challenge with the commonly described learning outcomes of a course is that they do not clarify the competencies that teachers should include in learning activities, provide feedback on, or assess in a clear and straightforward manner. For this very reason, the DesCA (Design Competency Assessment) framework was developed in collaboration with instructors of design courses and courses with design components at SUTD [18]. A competency framework should allow a more fine-grained identification of the competencies that a course, curriculum or program wishes to furnish its students and of the levels of competency expected at specific points in their learning journey, thus supporting the development of progression pathways. Learning activities, experiences and materials can then be designed to fulfil these needs [19]. A competency framework should also provide a common language for curricula, courses and activities that involve multiple disciplines, such as design projects. At least in design education, approaches, methods and tools do not provide a common ground.
In this paper we present a case study aimed at a first evaluation of DesCA's effectiveness in (1) identifying design competencies in the courses involved, (2) linking competencies to a time-based course structure and (3) providing a "common language" to improve collaboration between courses of different disciplines.

2 DESCA FRAMEWORK

From a literature review we inferred that competency refers to a comprehensive term that encompasses knowledge, skills, attitudes, and behaviours that are essential for an individual to succeed in professional, social, or learning settings [20]. When we refer to "design competencies," we mean the competencies required for designing. We believe that design can cultivate a wide range of competencies that can be applied in other courses and activities. At the same time, a wide range of courses can cultivate competencies that are required for design. Many of these competencies are discipline agnostic.
The DesCA framework was developed to help faculty identify design competencies in their courses (whether design courses or not) and provide them with a common vocabulary to collaborate effectively when planning, teaching and assessing design (especially in design activities such as DTP and DTI. The framework aims to: (1) provide an outline of a design process; (2) link design competencies to the phases of this process; (3) assist with determining the design competencies and levels of competency the course or curriculum aims to achieve; (4) suggest possible methods and tools based on the chosen competency and competency level; (5) guide the formulation of design deliverables and related learning outcomes; (6) support the assessment of learning outcomes based on competencies and deliverables [18]. The case study described in this paper addresses aims 2 and 3.
An action research approach was used to develop and evaluate the DesCA framework. In the first stage, the structure and initial content of DesCA were developed based on a literature review of accreditation requirements for design and design engineering courses [21, 22] and of some established frameworks [23–25], the material of the "Design Thinking and Innovation" (DTI) and the final year Capstone Design course at SUTD as well as on discussions with their leads. In the second stage four design and four non-design faculty were interviewed to gather their understanding of competencies and challenges and successes in fostering or assessing competencies. Valuable insights into required competencies were also obtained from design educators across other levels of education [20, 26]. The third stage involved applying the set of competencies through workshops and interviews with 33 faculty involved in 28 courses at SUTD to evaluate the applicability of the set by faculty of different disciplines, to analyse the students' perception on the competencies they learned in those courses, and to analyse the coherence, links, and progression of design across the curriculum [29]. This led on the one hand to changes in the courses and on the other hand to refinement of the list of competencies and the development of support for deconstructing the course content into competencies.
The DesCA framework currently includes 103 skills, 81 knowledge components, and 67 attitudes, all of which are linked to 12 overall abilities related to the main phases in a design process.
To support identifying competencies, DesCA includes: guidelines to distinguish between abilities, skills, knowledge, attitudes; a form (Figure 1) and a sequence of questions to identify abilities, skills,

knowledge and attitudes: (1) What abilities are being fostered? (2) What skills are being trained? (3) What knowledge is being imparted? and (4) What attitudes are being inculcated? In addition, we adapted Crawley's categorization of learning outcomes for the CDIO (Conceive, Design, Implement, Operate) syllabus for engineering education [23] to classify competencies as being introduced (I), taught (T), assessed (A), or expected (E) [23], [29].

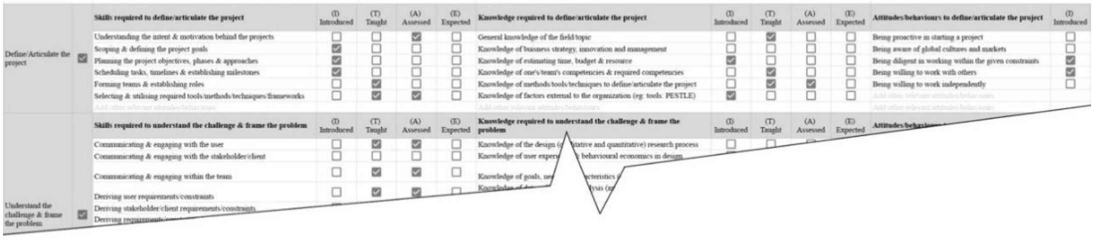

Figure 1. Course Competency sheet with abilities, skills, knowledge, attitudes and whether they are being introduced/taught/assessed/expected in the DTI course

We found that while faculty could easily indicate which of the 12 overarching abilities their courses foster, differentiating between skill, knowledge and attitudes is often challenging. To overcome this challenge and minimize subjective interpretation, we have identified pointers. They are as follows:
Abilities: This category can be identified using the learning objectives and measurable outcomes of the course and by asking the question "What do you want students to be able to do by the end of your course?". For example, students should "*be able to"* define and articulate the project.
Skills: These are characterized by verbs (ending in -ing) followed by the context and, by asking "What specific actions are students expected to perform?". For example, they are defin*ing*, articulatingi*ng*, identify*ing*, the problem, project (context), etc. We refer to Bloom's Taxonomy [27] for a list of verbs.
Knowledge: Once the skills have been identified, it can be difficult to relate what specific knowledge is required to perform them. It requires a deep understanding of the content covered in the course. In most cases, the knowledge component is related to the context in which the skill exists and can be identified by asking "What do they *need to know…?"* For example, students would need knowledge of the problem, project, etc., to perform the desired skill effectively.
Attitudes: We differentiate this category from skills and knowledge by adding "being" to the noun form of the verb and by asking the question "What specific attitudes should students exhibit?". For example, the course facilitates desirable attitudes, such as being proactive, being willing to learn, etc.
These pointers us helped us with the mapping competencies for the DTI and DTP courses which were part of our case study.

3 CASE STUDY

The nature of the DTI course and the DTP proved apt for studying our research questions: Can DesCA, as described above, be used to identify design competencies, overlay these onto a time-based course structure and provide a common language for enhanced and effective collaboration between courses?

3.1 Case

SUTD employs a unique four-dimensional (4D) pedagogy in its Bachelor programmes. This pedagogy utilizes design challenges at different levels or dimensions: 1D design activities involve a single course; 2D design activities involve all courses in a particular term; 3D design activities involve courses from different terms; and 4D design activities are course-independent and extracurricular activities [15]. The case study focuses on the Design Thinking Project (DTP) ([12] for details) and the 4 courses it integrates: DTP and the courses take place in Term 2, are mandatory for all SUTD students, and are facilitated by faculty from different disciplines, including architecture, mathematics, physics, and engineering, to name but a few. DTP is a 2D activity taking place in weeks 10-12 (of 14) of term. DTP serves as an extension of Design Thinking and Innovation (DTI), a Term 2 course aimed at cultivating the design thinking process using the UK Design Council's Double Diamond framework [28]. The other 3 courses on which DTP – as a 2D project – builds are: Modelling Space and Systems (MSS- mathematical modelling of real-life problems), Science for a Sustainable World (SSW - science and engineering approaches towards achieving sustainable development), and Technological World (TW - physics foundation for a holistic perspective of current and emerging technologies in modern society). DTP's purpose is to bridge the gap between the different subjects in the term: students have to demonstrate how the content of the 3 courses have influenced their projects or how their projects have helped them understand these subjects more deeply. The DTP project takes place in weeks 10-12 of the 14 week Term 2 and is facilitated during the DTI classes by the instructors of the three discipline-specific courses along with the DTI instructor, to allow students to consult with the instructors on applying the appropriate discipline specific concepts in their DTI project. This application is the main focus of these three weeks (For a detailed account of DTP, see [12]). The multi-disciplinary nature of the DTI course and the DTP project made them apt to study our research questions.

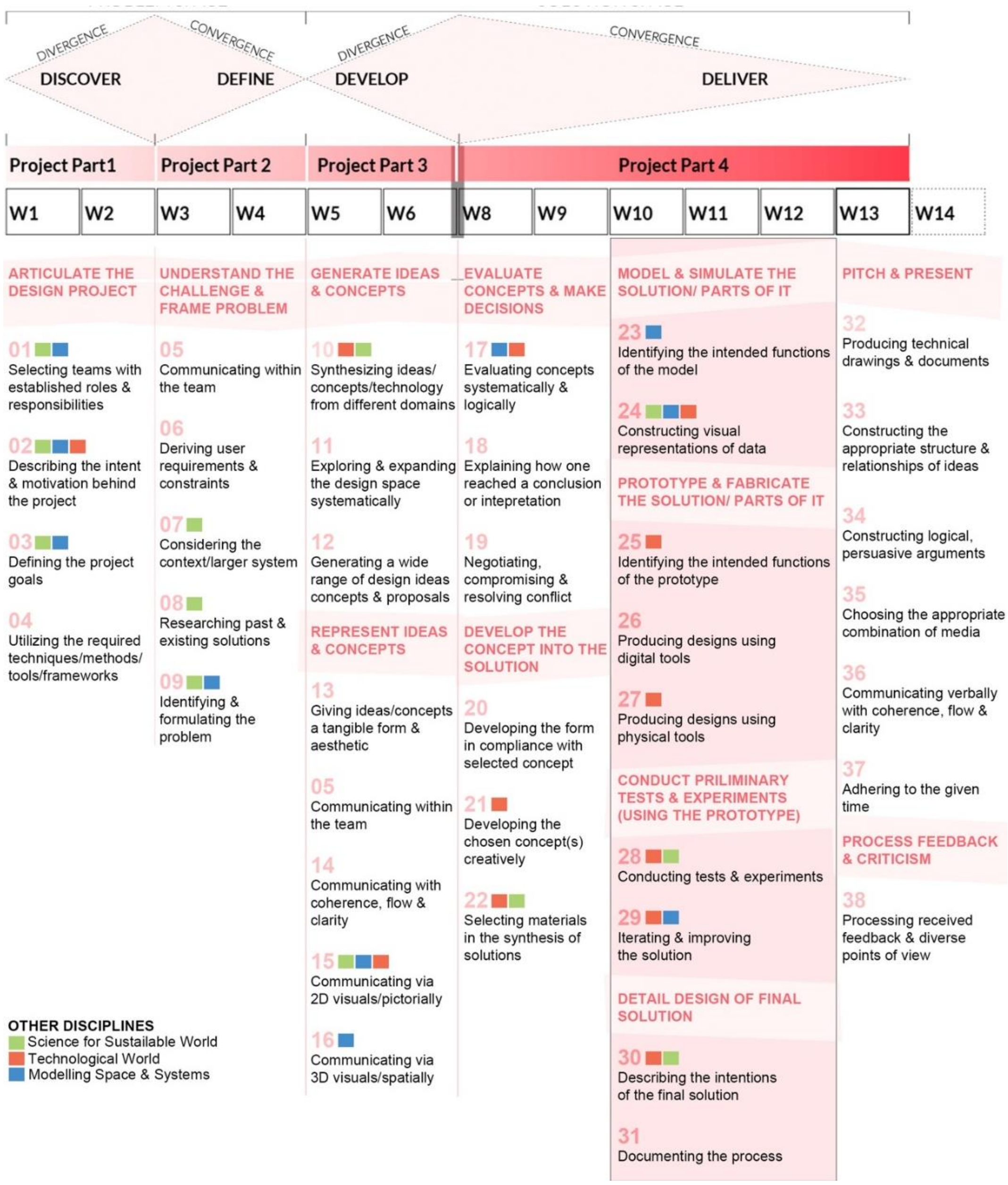

Figure 2. Competency-based plan for DTI showing 38 design competencies and the Double Diamond framework against the term weeks. The coloured squares indicate contributions to the design competencies by three non-design courses in that term and pink column indicates DTP project weeks

3.2 Results

Together with the course leads, we used DesCA's list of competencies and support described earlier to first identify the competencies for DTI (Figure 1) and for DTP and whether they are introduced, taught, assessed, or expected. The DTP design competencies are those fostered in the three discipline specific courses MSS, SSW, TW. Next, the four phases of the Double Diamond design process used in DTI were mapped against the weeks of the term (see Figure 2), followed by the mapping of the DTI abilities (red in Figure 2) and the related competencies (black). To maintain clarity and focus teaching and assessment, only the competencies that, according to the course leads, are being taught or trained explicitly, were included. Interestingly, this was only the case for skills and knowledge components. None of the identified attributes are explicitly taught or trained in DTI, yet. Finally, coloured squares were added to indicate whether a particular competency is being taught in one of the three discipline-specific courses. The scheme shown in Figure 2 is now used in the weekly DTI instructor meetings to reflect and actively used by the course lead for monitoring and planning during the course.

4 DISCUSSIONS

In earlier interviews the instructors of DTI and DTP reported having limited knowledge of what was being taught in the other courses, despite being expected to facilitate the cross-course DTP project. We observed that describing the courses in terms of competencies, providing forms and guidelines, and mapping the competencies against the course timeline and the design process model used, was effective in identifying and presenting competencies, in planning and monitoring when they were being addressed, and in providing a common language for instructors to discuss course content across disciplines. We expect that collecting this data for every course, a comprehensive understanding of the design competencies fostered across the curriculum could be obtained, supporting course and curriculum planning and coherence. The application of DesCA highlighted early in the term different perspectives on the course among faculty, possibly due to their background, which could affect teaching and assessment if not identified. It has to be noted that the courses take place in multiple rooms in parallel, each with their own instructors. The use of the schedule (Figure 2) in the instructor meetings helped instructors and course leads monitor and reflect on progress and take action if required, ensuring more coherence between classrooms.

The case study could only start a few weeks prior to the term. This affected the time available for training of the instructors and the possibility of adaptation of the course during the planning stage, e.g., the explicit training of some attitudes. Not all faculty are equally involved in the case study. Possible reasons are a lack of time or of interest. The case study is still ongoing at the time of writing this publication, so that final conclusions cannot be drawn yet. Additional case studies are necessary to confirm the findings.

5 CONCLUSIONS

Education has evolved from traditional discipline-based curricula to integrated education that focuses on knowledge application and generation. The complexity of global challenges necessitates a broad range of knowledge and skills, including those related to design, which is essential for problem-solving and innovative solutions. However, challenges exist in implementing teaching and implementing design throughout the curricula. The DesCA framework was developed to address these challenges by providing a competency-based approach. The case study shows that DesCA's list of competences, the form and guidelines, can help instructors of different disciplines and in the context of an interdisciplinary project (1) to identify design competencies, (2) plan a course, establish its links with other courses, and monitor progress through mapping the competencies onto a time-based course structure, and (3) provide a common language enhancing communication and collaboration between instructors within and between courses. Further case studies are necessary to confirm the results and improve the framework. We hope that the method to map competencies, the use of a competency framework and the resulting visualization can serve as a model for programs seeking to integrate design into their curricula.

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A STEAM X D WORKSHOP FOR PRE-UNIVERSITY STUDENTS: PREPARING STUDENTS FOR TRANSDISCIPLINARY APPLICATIONS

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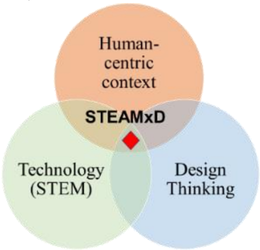
ABSTRACT
In this work, we introduce the Singapore University of Technology and Design (SUTD)'s STEAM x D (STEAM = Science, Technology, Engineering, Arts and Mathematics, and D = Design Thinking) multidisciplinary collaborative workshop, which was carried out for a total of 46 participating high school students (16-18-years old, 30% female). In this 5-day workshop, the students collaborated in teams of 4 to 5 members and interacted with 10 SUTD faculty members from several disciplines, 11 SUTD undergraduate helpers, and students from the Multi Rotor club to solve a design challenge. As part of our daVinci@SUTD immersion programme, which seeks to inspire youth in human-centred design and innovation that are grounded in STEM education fused with the understanding of Humanities, Arts, and Social Sciences to serve greater societal needs, students used a systems approach complemented with human-centric, design thinking, and technology-based elements, which prepared the students for a transdisciplinary application of competences. In general, survey feedback showed high levels of student engagement, awareness of using engineering, technology, and design thinking to solve real-life problems, and an overall students found the workshop useful. Design thinking was used to bridge the societal context (humanities, arts and social science) of real-life problems to the engineering and technological solutions through an interdisciplinary systems approach. This work will benefit those interested in transdisciplinary education, engineering design education, and those interested into finding principles for amalgamating faculty from different disciplines to work together into a meaningful and impactful project that prepares students towards a transdisciplinary application.

Keywords: Design Education, STEAM, workshop, interdisciplinary, multidisciplinary, transdisciplinary

1 INTRODUCTION
The SUTD curriculum places its emphasis on design-based projects focusing on active and hands-on learning [1] – [10]: starting from Freshmore year (defined as the first 3 terms - 2 terms in freshmen and 1 term in sophomore) to pillar years (terms 4 to 8), and finally ending with a 2-term long capstone (industry related) project (terms 7 and 8). This unique Big D framework empowers students to learn beyond the normal textbook knowledge and encourages a hands-on independent active, hands-on learning culture, ultimately leading to transdisciplinary application during a capstone project.
The STEAM workshop (STEAM = Science, Technology, Engineering, Arts and Mathematics, and D = Design Thinking) was structured as a designette [11] [12][13] wherein participants were provided with a design brief containing an opportunity statement, workshop narrative, deliverables, rubrics, and metrics. Students applied a design systems approach, which included: human-centric context, technology (STEM), and design thinking. The human-centric design developed a narrative of the workshop to highlight the humanistic component of the design challenge. The technological component ensured the transferring of abilities through a series of sessions to enable the participants to prototype appropriate solutions, while design thinking provided design tools to the to find potential solutions, but, most

importantly, bridged the other two components to drive the workshop towards a collaborative outcome, see Fig.1 (left).



	AM (9:00 am – 12 pm)	PM (2 pm – 5:00 pm)
Day 1	**Session 1: Societal Context** Workshop narrative, Humanities session, introduction to the Design Brief.	**Session 2: Design Thinking** Project design brief and design thinking activities.
Day 2	**Session 3: Physical World of Drones Session** Drone assembly, flight dynamics, forces at play.	**Session 4: Coding world of Drones Session** Block-based visual programming and learning to fly a drone.
Day 3	**Session 5: Space-age Fabrication Technologies** Training on using Automaker Fusion360 and Cura to prepare printing file.	**Session 6: Makers Space** 3D printing exercise and laboratory tours.
Day 4	**Session 7: Math & Analysis of Drones** Modelling and optimization of task (flight path) through the Traveling Salesperson (TSP) problem.	**Session 8: Experimental Design** Challenge preparation (Storyboard + prototyping + drone practice)
Day 5	**Session 9: Final Test Run:** Last minute preparations for competition and storyboard pitch.	**Session 10: Design Challenge Day** Drone competition + storyboard pitch.

Figure 1. STEAM x D lies at the interface of the human-centric context, technology, and design thinking (left). The workshop is created on a contextual reality, driven by Design Thinking, and implemented through STEM. Daily programme timetable (right)

According to a study by Dr Graham [14], the engagement of STEM to youth should be before university. Thus, a pre-university, a 5-days collaborative STEAM x Design Workshop was formulated and conducted in earlier January 2022 for 46 students (16-18 years ago) [15]. The 5-days programme was designed with a weekend (2 days) as an intermission for the purposes of providing reflection time for the students as shown in Fig 1 (right). Each day was separated into 2 segments (AM and PM) for the purpose of providing abilities-transferring training sessions. The participants were introduced to a design brief wherein the workshop was titled "Covid-19 Vaccine Cargo Airdropped to an Isolated Village Using Drones." In addition, participants were introduced to a workshop scenario where they took the role of SUTD entrepreneurs (TECH NGO) undergoing a series of training sessions to rapidly acquire competencies needed to deploy a comprehensive cargo delivery service to remote areas. Finally, participants developed a problem scenario which included deliverables for day 5: (1) a drone challenge with its metrics, and (2) a storyboard 3-min pitch with its rubrics.

2 THE DESIGN WORKSHOP PROGRAMME

2.1 Day 1 AM Session 1: Socio-historical Context

SUTD's STEAM x Design pedagogy foregrounds the importance of human-centred design. In the workshop, we highlighted its importance by introducing a session on equitable design run by faculty members from the Humanities Arts and Social Sciences (HASS) cluster. HASS' main learning objective was to enhance the ability of the students to (1) identify and analyse socio-historical contexts of the drone service and (2) ensure equitable access to medical supplies. To that end, the session introduced two key principles: equity and empathy through interactive discussions and hands-on exercises. Using the World Health Organization (WHO) and World Bank databases, students first examined the correlation between Covid-19 vaccination rates and per capita GDP of Singapore, Nigeria, and India, to quantitatively explore global inequities in vaccination. Each group was then assigned a particular location for drone delivery in either Nigeria's Kaduna State or India's Himachal Pradesh. Students then went over academic journals and newspaper articles to gather more information about their locations, including challenges faced by historically marginalized communities in these areas. Specific challenges included vaccine scepticism, religious-based opposition to the use of vaccines, and a history of marginalization from medical services. Their exploratory research culminated in the *persona* exercise, where students developed a user profile to concretize their understanding of the specific cultural context and needs of communities in the location assigned for their drone delivery service. Based on this user profile, the students were then ready to begin work on their storyboard during the Design Thinking session in the afternoon session.

2.2 Day 1 PM Session 2: Design Thinking Tools/Methods

Students were introduced to the UK design council's framework for innovation: the *double diamond* design thinking framework (discover, define, develop, deliver) as a guiding tool to the workshop deliverables. The discovery and define components of the design thinking process were finalized during this session through a series of tools/methods, such as *affinity matrix*, *storyboard, morphological matrix and c-sketch.* The session culminated in a redefinition of the problem statement from the design brief. By the end of the day, students had a clear idea of the deliverables expected for Day 5: a storyboard pitch and a drone challenge. A sample of the student working on the storyboard is shown in Fig. 2 (left).

Figure 2. Students working on their storyboard during their design thinking session in day 1 (right), and training session on VB programming of the drones in day 2

2.3 Day 2 AM Session 3: Physics World of Drones

Students learnt about the forces and torques that control the flight behaviours and dynamics of a simple quadrotor drone, and how to control the balance of these forces to make the drone fly in the air the way we desire. After introducing the basics of flight and how a multi rotor achieves controlled flight by actively regulating the speed and thrust of each of the 4 motors, the students moved on to flying an actual multirotor drone using a specialized controller (a stick controller). This specialized controller contains 2 joysticks that are controlled by the index and thumbs of each hand to allow independent motion of the drone in the altitude, yaw, roll and pitch axes. Since controlling all 4 motions at once is quite challenging for a beginner (it is akin to learning to ride a bike - learners must simultaneously balance as well as coordinate their arms and legs), we started off with just control of 1 direction (vertical up and down) and getting students familiar with altitude control (left stick). Once students were familiar, they then combined the altitude (left stick) control with the lateral motion (right stick) of the drone. Once students were able to do so, they then followed a pre-defined obstacle course and practiced their piloting skills.

2.4 Day 2 PM Session 4: Coding World of Drones

Once the students have mastered manual piloting of the drone, the next step was to program the drone to fly autonomously. Such an operation requires programming skillset from the students. To allow students who are new to programming as well as provide an avenue for more experienced students with programming background to leverage on each other, we elected to employ Visual Block Programming (VBP) to introduce the basic mechanics of programming and relate these concepts to an easily relatable 3D positional control of the drone. VBP is a kind of programming language that lets user create programs by manipulating program elements graphically rather than specifying them textually. It allows rapid programming with visual expressions, spatial arrangements of text and graphic symbols, such that it is synthesized in a manner that makes sense to humans (as opposed to text-based which 'forces' the programmer to think like a computer) as shown in Fig. 2 (right).

2.5 Day 3 AM Session 5 and PM Session 6: CAD for Additive Manufacturing

One of the challenges given the students was to fly the drone with a payload (a lightweight yet soft spherical ball) to mimic the delivery of a vaccine cargo to a designated location. To achieve the challenge, students needed to design via software and use 3D printing to fabricate a simple container that can hold the spherical ball yet allow for an easy drop-off of the payload. We took this opportunity to introduce computer-aided design (CAD) using Fusion360 software to design and model a simple bowl-shape container as shown in Fig. 3. Students experienced a typical workflow of modelling in Fusion360 and learned different basic functions, such as extrude, evolve, mirror symmetry, constraints, and fillet. Specifically, we emphasized parametric modeling as it provided flexibility for design modification and improvement later. Finally, we made use of Ultimaker Cura software to convert a .stl format 3D file to a g-code format file for 3D printing in the next session. In this session, students used a AnyCubic i3 Mega-S FDM 3D Printer in our SUTD Fabrication Lab (Fab Lab) to print their payload container. We also arranged a lab tour to the Fab Lab and the SUTD Digital Manufacturing and Design (DManD) Centre to broaden students' horizons on numerous possibilities of 3D printing in industry and research in various applications, manufacturing processes, and fast prototyping.

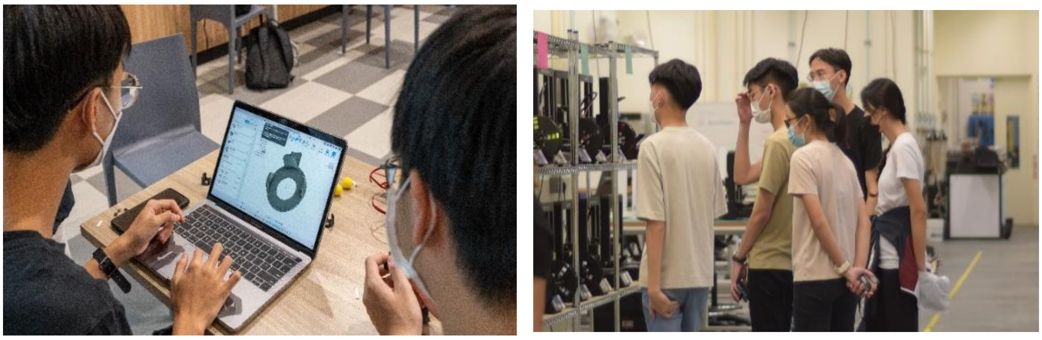


Figure 3. Training session on CAD drawing using Fusion360 (left) and students experiencing the 3D printing facility in the SUTD FabLab (right) in Day 3

2.6 Day 4 AM Session 7: Math Analysis of Optimal Fly Path

Following the lessons on how to fly a drone using VBP in Day 3, the students learnt how to design the route of the drones by re-casting the problem as a Traveling Salesman Problem (TSP). The key objective of the session was to teach students how to minimize the time taken for each flight path since each drone was only able to fly for a limited amount of time. Students were exposed to various strategies to find the most optimal path and were shown examples of how the TSP problem is applicable to many other applications, such as in manufacturing processes and in scheduling. As a simplest example, students were taught the brute force method to exhaust all possibilities to find the most optimal path. As a scaffolding exercise, students were first asked to calculate the number of ways for a journey with n vertices to complete the trip, and this was related on their prior knowledge on permutation and combination that they have learnt in school. The instructors then provided the students with a mock example containing 4 vertices and they were tasked to compute the shortest path. Through these two discussions, we introduced the idea of computational complexity, allowing students to appreciate that the difficulty of the brute force approach scales rapidly with the number of vertices. After demonstrating the tedium in solving the problem by hand, as part of a hands-on activity, students were taught how to generate the most optimal path using Microsoft Excel Solver, as well as to visualize the optimal path automatically on a generated graph within Excel.

2.7 Day 4 PM Session 8 and Day 5 AM Session 9: Experimental Design

In these sessions, students had the flexibility to organize their time and efforts according to their priorities and needs.

2.8 Day 5 PM Session 10: Drone and Storyboard Pitch Challenges

The exciting final challenge arrived for the students on Day 5 of the STEAM x D Workshop. The drone challenge required all teams to integrate and combine all the skills learnt during the sessions to complete the challenge task that was related to the overall theme of vaccine delivery using drones. To start, each team had to first modify and retrofit the drones provided to carry up to 2 vaccine payloads, which were achieved by using computer-aided design (CAD) and 3D printing technologies (from Day 3). As per the scenario, to minimize transmission of the virus, this aerial delivery had to be done without human pilots and the flying mission needed to be fully autonomous and attained through VBP programming in an optimized path (from Day 2 and Day 4). Each team needed to utilize the onboard 8x8 LED screen to inform the local population (who may not understand written language) that the team was non-hostile and was carrying medical supplies (from Day 1). Each team operated in a 12 x 7 m^2 region that was separated into 1 m^2 grids. Every team was assigned 5 random coordinates. One of them will be the home coordinate (where the team is home based) and the 4 other coordinates are where the team's drone needed to traverse. The order of the coordinates had to be optimized by minimizing the total travelling distance (TSP from Math in Day 4). At each of these 4 coordinates, the drone was required to carry out specific tasks (e.g., technological demonstrations, such as: land and take-off, 360-degree visual scanning, LED illumination, and payload release). These tasks must be fully automated and can only be carried out through programming using VBP (programming). The overall scoring was dictated by how precise the drones were able to reach each of the coordinates in the correct sequence as well as carry out the correct task at each coordinate. Teams were allowed unlimited tries within a 12-minute window and each team scored points by executing the correct task at the correct waypoint (see Fig. 4 (left)). Teamwork was critical as all these tasks were required to be carried out concurrently. As there were 2 teams flying within the same zone, teams needed to also communicate with each other to deconflict the flight zone.

Students in each group were given 3 minutes to give a storyboard pitch to convince the judges that they had the best systems-approach solution to deliver Covid-19 vaccines to rural villages. Each group was assessed based on their cultural sensitivity, geographical considerations, understanding of technology, logistics planning, clarity of message, and their unique selling point (USP). There were five judges, each with a different background (academic and industry) and disciplines (Social science, Physics, and Chemical Engineering).

Figure 4. A team executing their design fly path for a given set of coordinates (left), and a team during their 3-min storyboard pitch on day 5 (right)

3 WORKSHOP SUMMARY

Overall, here are some salient points, which are summarized in Fig 5.

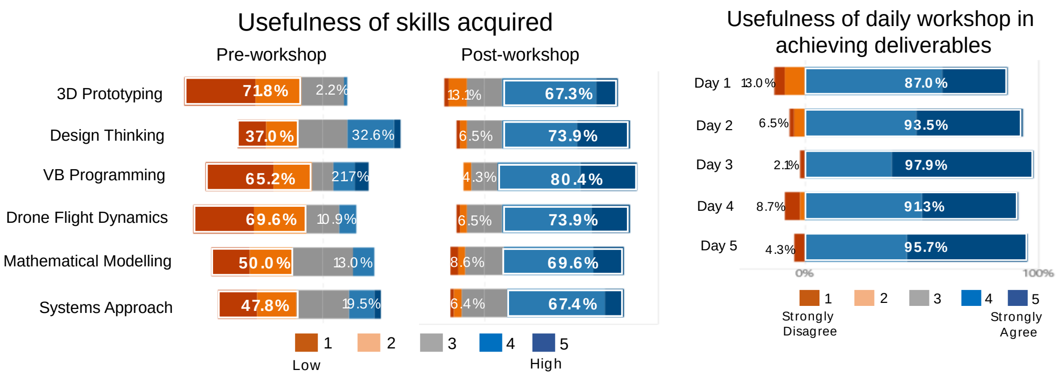


Figure 5. Student feedback on usefulness of skills acquired (left), and usefulness of daily workshops in achieving the deliverables on day 5 (right). Areas of improvement are the Design Thinking session and the emphasis on the Systems Approach.

All (100%) students agree that the workshop allowed them to experience, learn and apply human-centred design, technology, and engineering to solve real-world problems. Majority of students (> 80%) are more likely to consider undergraduate studies in engineering or technological design after this workshop experience. The students enjoy the most *Hands-on learning*, *Teamwork* and *Socio-historical context* of the workshop. All skills taught were found to be valuable (67-80%). The hand-on sessions are viewed extremely positive especially the 3D printing session on day 3 and the Design Challenge on day 5. And all sessions were found to be relevant in achieving the deliverable tasks on day 5. Overall, we believe that this unique 5-day collaborative workshop represents a unique opportunity to equip students with competencies required for a transdisciplinary application in a real-life context, wherein students are expected to problem solve in a different contextual setting. Furthermore, bringing faculty members to work together across their disciplines (Humanities, Design, Physics, Engineering, Mathematics) to create a workshop which larger than its parts was a novelty.

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EDUCATING RESILIENT AND WELL DESIGNERS

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ABSTRACT
In this paper, we explore how resilience and wellbeing can integrate into, and improve design pedagogy. We establish 10 principles for designer resilience from workshops with students, educators and design practitioners. Each principle offers a platform to develop subsequent learning activities that remedy hollow didactic statements observed in education and research discourse (embrace complexity, navigate uncertainty and ambiguity). Future research will report on the results of integrating these principles and subsequent learning activities into a revised Master of Science design curriculum.

Keywords: Design, education, resilience, wellbeing, pedagogy, didactics

1 INTRODUCTION
Our Faculty of Industrial Design Engineering, like so many globally, celebrates outstanding alumni and their achievements as evidence of impact. Stories of *pioneering* change through new products, services, and systems are championed to past, current and future students, as well as to academic staff and industry professionals. On the first day of their studies, new design students also receive textbooks on methods, skills and core knowledge. With this subtle combination of championing pioneers and providing foundational textbooks, we convey that these students can one-day pioneer too. However, pioneering change is fraught with setbacks, uncertainties and resistance to change that drives even experienced designers into vulnerability and doubt [1]. Comparatively, in our education studios and research discourse, we observe the prevalence of hollow didactic statements. We ask our students to, 'embrace uncertainty, ambiguity and fail fast.' From a didactic point of view, these statements hold no value (akin to asking somebody to eat healthier or fly less). It is a worthy endeavour to improve design pedagogy beyond hollow didactics in order to deliver our most courageous and adaptive graduates yet - ready to pioneer much needed change in the world and resilient enough to enact it.

1.1 Resilience and Wellbeing in Higher Education
Higher education (HE) students experience rates of depression substantially higher than found in the general population [2]. One avenue for supporting student wellbeing and academic performance in HE is the positive psychology construct of resilience. Resilience is the ability to bounce back from adversity and cope with stress [3]. Psychological resilience is formed through life experiences and acquirable through cognitive and behavioural training [3]. While many universities tend to enable student wellbeing through 'separate services' such as student psychologists and health programmes, we argue that the way we shape education is a key factor to promote the flourishing of students, and teachers too [4]. We can learn a lot from fields such as nursing, medicine and environmental science who have already integrated resilience activities into higher education curriculum to prepare graduates for practice [5].

1.2 Designer Resilience and Wellbeing
We propose the need for *designer resilience* as a discipline specific blend of general and specific types of resilience that apply to and synergize with design practice and theory [5]. A working definition of designer resilience entails: (1) 'bouncing back' to perform in spite of adversities faced in design projects; (2) undergoing adaption without significant loss of function during setbacks faced in design projects; (3) growing overtime as a tolerance or 'a thicker skin' to adversities/uncertainties faced, and; (4) deliberately building peer networks across the design discipline and beyond for collective support.
General design resilience includes dealing with critique and negotiating the balancing act of performance and learning-driven outputs. Specific contextual resilience includes dealing with systemic

ambiguity when working in complex societal contexts; emotional resilience when working with vulnerable target groups; and the resilience required to deal with negative outcomes when working as a design entrepreneur. As an important distinction, we define wellbeing as a broad and continuing state of health, while resilience is a specific capacity drawn upon when dealing with setbacks and negative events to protect wellbeing [5].

2 METHOD: CO-CREATION WITH THE DESIGN EDUCATION COMMUNITY

2.1 Research and design objective

In this paper, we report on research-in-progress to develop and integrate designer resilience in a Dutch University context. The designer resilience project is part of a broader programme of initiatives that we have undertaken over the past seven years to improve student wellbeing [6, 7]. Research questions structuring our inquiry are: (1) what do students experience when becoming a designer? (2) what behavioural principles support students in becoming resilient designers?

2.2 Research method

Central to our funding body, the Netherlands Initiative for Education Research, is the need to conduct educational research that is *student centric*. Therefore, over the last twenty- four (24) months, we have undertaken a collaborative research-through-design approach with iterative workshops with Master of Science students at the Faculty of Industrial Design Engineering, at Delft University of Technology. As authors, we are design researchers and educators who place a strong emphasis on teaching quality in our academic careers. Throughout this project, we have stayed true to our designerly mindset and background, in order to learn our way forward through workshops, interactions, activities and interventions [4]. To date, we have engaged over 300 design students in our resilience and wellbeing workshops. We have also engaged fifty (50) global design teachers and thirty-six (36) senior design practitioners to ensure that our project receives broader perspectives of practice and research. In total, we have conducted eleven (11) workshops. These workshops range in duration from 90 minutes to full day sessions.

While each workshop shares a general introduction to resilience and wellbeing, we zoom in on specific topics within each workshop, including but not limited to; coping with the pressure to perform; querying how physiological stress limits creativity, and forging your own career path. In this conference paper, we firstly zoom in on data from a recent workshop where we asked students to reflect on their experiences of becoming a designer and required resilience. Secondly, we share behavioural (resilience) principles that we developed and tested iteratively across the most recent eight (8) workshops. Our analyses and reflection approach consists of a thematic analysis of notes of students written on sticky notes within workshops, reviewing our own workshop notes, reflecting on our experiences as educators and recalling participant anecdotes that left a major impression on us within workshops. As with previous research, we accept the limitations of our approach in order to prioritise student engagement [6].

Sessions are not recorded due to the sensitive nature of discussing wellbeing, setbacks and resilience. In the planning and execution of the workshops, we received instruction from Faculty Academic Counsellors' who are trained clinical psychologists. Their instructions ranged from how to construct a safe workshop environment, how to discuss sensitive life events and how to encourage engagement without overstepping our role as educators. Future research must conduct the same liaison with psychologists prior to workshops with students.

3 EXPERIENCES OF BECOMING A DESIGNER

In this section, we present findings with regard to the different types of challenges that design students report and the different forms of designer resilience we can identify accordingly.

3.1 Design process and collaboration resilience

Students report many insecurities that are inherent to the design process and learning to become a designer. Issues that students report difficulty regarding include, but are not limited to:

- Knowing what to do: "not knowing what to do next" or not having "grip on the process"?
- Knowing when to stop: "the process is never finished. When am I done?"

- Social aspects of a design process, including how to collaborate and work with clients, such as dealing with: “creative differences in a team” or “navigating different personalities” and “knowing when to listen to the client and when to trust your own expertise”?
- Knowing how to deal with critique: “presenting your personal design can be very scary” because you invested your “heart and soul into the design.”

3.2 Responsibility and concerns about impact

Students’ feel responsible for the impact that their designs (should) make on people, society and the planet more broadly. For example, “the feeling of 'you need to solve this, otherwise nothing will change.’” They indicate feeling insecure and powerless about the impact they feel they should make, versus what they are realistically able to do. As one student states, “they are [sic] feeling like humanity is ruining the planet and our future is doomed.” Another reports, “feeling like the problem you are designing for is so difficult to solve that you will not be able to make a meaningful contribution within the time frame of the project.”

Students report that they are aware of the risks of working with vulnerable people. One student states they are, “worried to ask the wrong thing or trigger negative emotions, experiences” while also feeling responsible to design something that will help people. Students collectively describe a feeling of, “having to create the perfect design to make your users happy.” Finally, in terms of impact they worry about financial trade-offs that they will have to make regarding societal impact, for example should you work with a client who does not hold the same values? And, when to say ‘no’? For example, a student reported being afraid of, “being forced to continue with ethically questionable decisions” in their career.

3.3 Perfectionism, confidence and pressure to perform

Many students indicate traits of perfectionism, as one remarks directly, “I want to do everything perfectly [sic].” Perfectionism manifests in showing fear of making the wrong choices, “second guessing choices” and “being indecisive.” For example, having low confidence in the quality of their designs, “being overly critical of their [sic] own ideas” and “not feeling good enough.” Students also engage in benchmarking. As one student remarks, “working harder, doing more, having a bigger MIRO board means your design project will be better.” This encourages speed and volume rather than reflection and synthesis. Another student reflects more broadly, “I didn’t look at myself. I only looked at others and thought I needed to go fast. I made rash decisions that didn’t work. When I slowed down and reflected [sic], things changed for the better.”

To avoid benchmarking and the punitive side-effects of ‘falling behind’ or underperforming in relativistic terms to peers, students withdraw from one another. As one student states, “in the graduation (thesis/capstone), the collaborative atmosphere just disappears. Everyone just stays in their ‘own lane’ on their own project.” Perfectionism can also lead to students being conservative in their engagement with their own projects. Students keep “something in reserve in projects to protect themselves if they don’t get a high grade.” Students described using this approach to insulate themselves from critique knowing that, “I didn’t give everything, so I also didn’t get hurt.” Interestingly this perfectionism also plays out in how they think about their careers, reporting “not knowing what to invest time in, to lead a desired life path” and being afraid of, “not having the job you would like to get and therefore [sic] ‘settling for less.’”

3.4 Design identity

In addition to a lack of confidence about their design quality and design process, students report a more general ‘disciplinary insecurity’ about what value they will be able to offer as a designer in their own career path. Insecurity about the value of design includes being concerned about, “people not understanding the value of design.” Students particularly indicated insecurity relating to other disciplines. One student describes, “finding [sic] a balance between designers and engineers.” Another describes, “being familiar with a lot of fields, but still an outsider and not an expert.” In addition, students mention insecurities about their own career path and design identity, collectively asking, “what is my expertise?” Finally, a student reports a feeling of, “uncertainty about job prospects and value I have as a new designer.”

3.5 Consequences for designer-life balance and engagement

The experiences of responsibility, perfectionism and not being an expert designer (yet), result in various mental health issues and impact on students' lives. Many students report issues in terms of feeling time pressure: "during the night I want to still finish things, I cannot go to sleep before it is done," and, "overworking yourself because you feel responsible." This time pressure results in stress when a student "becomes [sic] stuck during a project but still having to finish it for a grade." Multiple students also report not being able to shut off mentally. One mentioning it is, "hard to stop thinking about your work." Another reports, "sleeplessness when you can't find a proper concept or vision for the project." At the same time, students are aware of this impact on their lives and report that they want to learn how to not get too "personally attached" to their work. Conversely, another reported consequence is a lack of motivation, missing, "inspiration, passion and enthusiasm." Negative consequences for 'designer-life balance' are further exacerbated by pressures that result from being a student and having to meet course requirements. As one student remarks, "a lot of scheduled hours to work on projects, long days." Another, "the working days at Uni [sic] are very long, you often go there in the dark during the morning and also leave when it is dark. This often feels depressing."

4 FORGING DESIGNER RESILIENCE

4.1 A framework for designer resilience

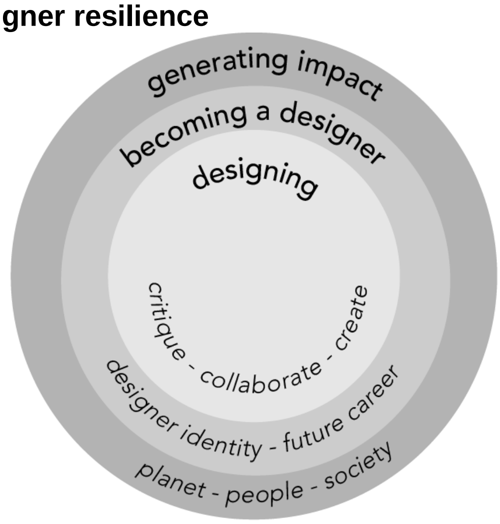

Figure 1. Layers of designer resilience

Based on our findings we identify different layers of designer resilience for students as indicated in Figure 1. On the most foundational level, each design students requires resilience to deal with the inherent challenges of the design process and of design collaborations. A next layer of resilience is aimed at shaping an uncertain future design career and accompanying design identity. Finally, we identify a contextual layer of resilience towards a feeling of responsibility towards people, society and the planet. In design education, we may address each of these layers by different means. For example, resilience towards designing might be best integrated in coaching within specific design projects, while resilience towards design identity and generating impact can be addressed in reflexive sessions that go beyond design projects.

4.2 Our vision on forging designer resilience

We believe that improving student wellbeing requires educational systems change, as we have argued in previous publications [1,5,6]. For example, we have tried to reduce the pressure to perform by advocating for the removal of unnecessary competitive elements in design education, and by introducing a community programme to improve students' confidence and generate peer support. However, we cannot nor should entirely protect students from the challenges and difficulties inherent to designing. We therefore aim to grow *designer resilience* in our lecture halls, classrooms, supervision and studios. We also aim to generate learning activities that inspire self-guided learning amongst students. An important way in which we try to achieve this is by introducing 10 principles for designer resilience that offer pathways to embed new learning activities into design education and therefore reshape curricula.

4.3 Ten (10) principles for designer resilience

These principles merge psychological resilience, systems and design thinking to scaffold meta-cognitive inquiry and reflection. At the core of these principles is the capacity for meta-cognitive flexibility, to be adaptive to changing and sometimes harsh environments. In future research, we will share the accompanying learning activities associated with each principle. The ten principles are:

1. **The resilient designer might be lost now, but knows every day and project is a step closer to finding their purpose.** Many of our students cannot articulate their direction and destination. Rather, they are on a journey of self-discovery, and we must coach/teach/supervise accordingly;
2. **The resilient designer takes decisive action to follow their purpose.** If a purpose is known, the resilient design is decisive to go beyond their comfort zone, even if that means creating chaos;
3. **The resilient designer is authentic to their identity and purpose.** Embedded in this principle is a strong sense of ethics. This principle calls the designer to stand boldly for their identity, even if that means being unpopular or contrarian;
4. **The resilient designer fuels their appetite to change the world with both hope and despair.** With a strong sense of empathy, it is acceptable that designers can feel despair at the injustices they see and wish to address. Hope provides the spark that converts us to action. There can be a better way, always;
5. **The resilient designer shares unfinished and unpolished work.** It is remarkable how young designers will hide their work for fear of rejection and criticism. This is counterproductive to the co-creative spirit of design and truly detrimental to deeper-level learning in HE.
6. **The resilient designer is reflexive to performance culture.** A performance culture can help us grow, but we must be reflexive to disconnect in order to prioritize our own authenticity and purpose;
7. **The resilient designer actively forms the environment in which they receive feedback.** When trying to pioneer systemic reform or drive radical innovation, one can expect a degree of resistance to change as people hold onto the status quo. The resilient designer takes care to construct the environment in which they will share work and thus receive feedback;
8. **The resilient designer trusts and drives their process.** We observe and find throughout our research that students often aim for ‘perfection.’ However, we know in design that perfection is an illusion. Rather designers work to satisfice a combination of constraints toward outcomes that are valuable, desirable, just, feasible, sustainable and viable. This synthesis is already difficult enough!
9. **The resilient designer views that ‘stakeholder alignment’ is temporary and that true pluralism and democratic dialogue means allowing diversity and therefore inclusion to drive value creation.** The more we open up our design process to new stakeholders and perspectives, the more difficult it becomes to reconcile these differences into a ‘solution’ that creates value for the many, not the few. Inclusive design takes time and can feel especially messy.
10. **The resilient designer actively shapes communities around them for collective support.** The resilient designer is actively developing a community of like-minded peers who are seeking to design for impact. Driving this community means contributing generously to the success of others. When the time comes to call for help from peers, the resilient designer is open to showing their vulnerability and seeking help from peers.

5 CONCLUSIONS

This funded education research explores how resilience and wellbeing as a way to unlock meta-cognitive flexibility and reflection can improve how we teach and learn design. We establish 10 principles for designer resilience. Each principle offers a platform to develop subsequent learning activities that remedy the hollow didactic statements we have observed in education and research discourse (embrace complexity, navigate uncertainty and ambiguity). Future research will prototype and report on the results from these new learning activities. Further, in subsequent dissemination, we will demonstrate how designer resilience is integrated into a revised Master of Science of Design curriculum at TU Delft for long-lasting impact.

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MIX REALITY, GAMIFICATION, AND SIMULATORS; THREE TYPES OF STRATEGIES TO INCREASE LEARNING IN THE TEC21 EDUCATIONAL MODEL

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ABSTRACT
During the pandemic, the use of remote laboratories helped maintain academic quality in the areas of Engineering and Science at universities around the world. At Tecnologico de Monterrey, we tried to go further using virtual, augmented, and immersive reality to give continuity to learning through the creation of digital twins during the confinement by COVID-19, and now that we have returned to strengthen the learning of complex lessons,
Using simulators replicating a manufacturing plant's operations allows students to better understand the transactions and generation of data formed by simulating the behavior during a determined period of demand. Gamifying the mixed reality lessons and simulators has allowed us to take learning to a high level of immersion on the part of the students. During distance learning, it was not easy to control the correct use of devices to avoid student distraction, now with the return to school, the use of these technologies allows not only an almost total immersion and increase in learning but also the development of graduation competencies not only of the students but also beyond the university.
A key element of learning in the TEC21 model is the challenge posed by a training partner, but one of the restrictions is the time they dedicate to us and the accessibility to their processes. Through these technologies, digital twins are being created that allow students immersive learning of the processes of the training partners and, for them, the current analysis of their processes and training of new personnel.
This document reflects the learning by designing, developing, and implementing mixed reality lessons, simulators, and gamification from August 2020 to date for the development of student learning in the TEC21 model.

Keywords: Mixed reality, gamification, simulators, innovative education, higher education

1 INTRODUCTION
In the 70s, the material requirements planning system emerged, given the need in the manufacturing industry to plan the raw material required to satisfy customer orders. With the development of various applications for production planning, the ERP (Enterprise Requirement Planning) [2] systems were born in the 90s; These systems sought to integrate all the main functions that interact in a company to make production processes more efficient.
The constant variations in delivery times motivated the root causes of said deviations to be investigated; among the leading causes identified are an inadequate integration of supply and demand, incomplete lists of materials, poor capacity planning, and the lack of integration and development of suppliers. The latter generated an exponential development of techniques for production planning, purchasing, and handling of materials. The problem is that many of these techniques work in isolation; Therefore, it is imperative to adopt a holistic approach that allows the interaction of several elements to achieve a common goal. This is how the systematization of tools that allow production planning that simultaneously satisfies the specific needs of the different companies is achieved.
In recent years, gamification has been designed in the industrial engineering department to support the teaching-learning process in statistics, quality control, and operations management. Among the most

distinctive approaches, we can mention the beer game, the Tec Motor Company simulator, and the Tec21 Car Assembler. See Figure 1.

Figure 1. Virtual Plant, Tec Motor and Beer Game playing for students

Since 2003, it has sought to design academic activities where knowledge of production planning, inventory control, design of experiments, quality, administration, and evaluation of projects, among others, can be reinforced and put into practice; Thus, the “Tec21 Car Assembler” was born under the STEM philosophy, [3] which was based on assembling scale cars using Meccano models [4].

2 METHODOLOGIES

In March 2021, due to the Covid-19 pandemic, the activity had to be redesigned to be used virtually, so the EON platform used augmented reality lessons with remarkable similarity to Meccano subassemblies, in order for the students to have an experience as similar as possible to physically doing the activity and visiting a car plant.

Based on the ERP (Enterprise Resource Planning) systems, the simulator was designed using systemic thinking to integrate the different activities of an assembly facility in a useful manufacturing process simulator. The students understood the importance of having a systemic vision that would allow them to understand the different flows in a productive entity and the interactions that must occur to improve, among other things, delivery times, availability of materials, and the general productivity of the company.

In 2018, the Tec21 car assembly plant was functional gamification [4], a physical simulation was implemented during the class. In each run, the aim was to enhance learning in a specific area. Using this concept, the simulator was developed with virtual and augmented reality support to make its use more attractive to students.

In the simulation, the concept of gamification is used in order to make it more attractive. When we play a board game, we are motivated to win; this sense of competition makes spending hours and hours in such an activity attractive. We engage students in the learning process by transforming methodologies and problem situations into fun challenges. The advantages of gamification [5] are the following:

- Make learning fun and interactive.
- Generates learning addiction
- It allows the student to see actual usefulness.
- Provides immediate feedback
- Gamification enhances the learning experience.

In this proposal, the most representative processes of a car assembly plant are replicated; It all starts with the customer, from which a purchase order is generated that reaches the materials buyers. When purchasing materials, the productivity index should be consulted because if the purchase order is for 40 cars, buying the spare parts kits for that product would be a mistake if the productivity index suggests buying more to counteract the production problems. Design and quality that may arise. Figure 2

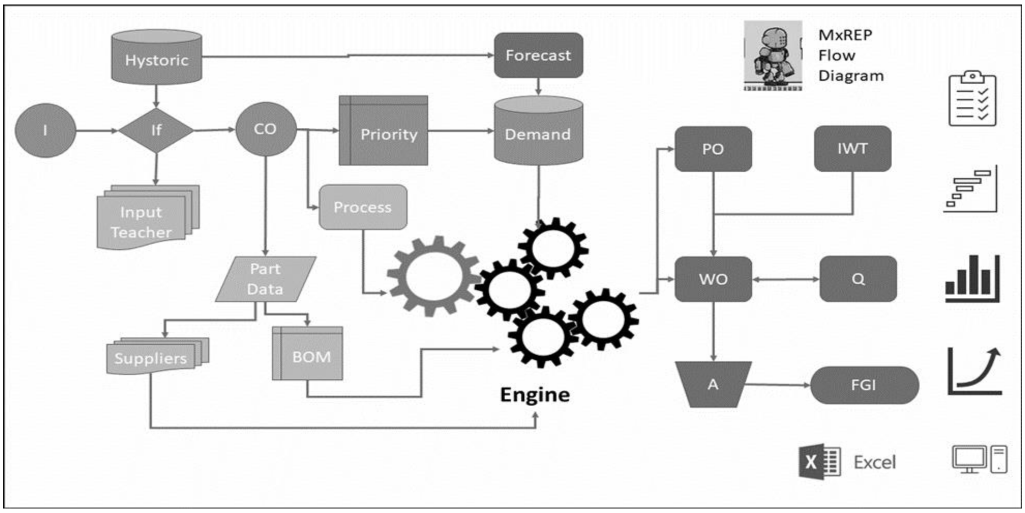

Figure 2. MxREP Flow Diagram

The simulation's programming is based on defining the processes involved clearly, mapping the flow of information, and delimiting it to the assembly of 5 different Meccano models, generating errors through probability distributions that substitute dice, hourglasses, perinolas, and other fun devices. Figure 2.
What is the advantage of this simulator compared to those already offered by other universities and system developers? The answer is that the simulator is wider than a single aspect of ERP. However, as shown in Figure 2, the simulator contemplates purchasing modules, customers, suppliers, demand, inventory management, product engineering, process, and quality, as well as logistics; which allows the simulator to belong to the spectrum, according to Deterding [6], of the concept known in English as "Gamification of learning," which refers to "the use of game elements in contexts that are not games" or "the process to make activities more like a game" [7]. The simulator offers a game-based learning alternative, which, when implemented in education, has multiple benefits, such as improving student participation, increasing their motivation, and encouraging curiosity, as well as generating attractive and enjoyable learning environments for the student, among many others.
As already mentioned, other simulators are available on the market whose concept is similar to the MxREP. However, they are limited to a single module and do not have the possibility of augmented reality. Universities such as Harvard and MIT have solutions such as the "Beer Game," Flexsim for discrete event simulation, or "Fishbank" [8] to teach about resource management, to mention a few examples. While Harvard has the Operations Management Simulation: Balancing Process Capacity and the Global Supply Chain Management Simulation, however, as has been mentioned, only one aspect of the ERP is analysed, and it is not complete, in addition to the fact that it can be parameterized by the teacher and the game has a graphical interface that is very attractive to the student.
Lost, [9] designed by Professor Pacheco at Tecnologico de Monterrey is an excellent supply chain simulator, based in probability distribution to emulate the customer orders, the constraints of lost are the products, which are defined by the designer, and don't have the MRP o Bill of Material visibility, the supply chain is rigid, and don't have the possibility to make a supply chain configuration.
The Table 1, show the comparative analysis between educational supply chain simulators developed by universities and business companies [10] and [11].

Table 1. Comparative analysis between the simulators developed by universities and business

Features	Simulators						
	Fish MIT	Bank	Beer game MIT	SAP	The production dice game	Lost Tec de Monterrey	MxREP Tec de Monterrey

ERP	Resource Management System Thinking	Logistics, production planning, process control	Procurement Production planning	Inventory Production line, Workflow	Logistics and procurement	Since CO is placed to delivery FGI in site of customer
Gamification	X	X		X	X	X
Simulator	X		X		X	X
AR & VR	2D	2D				2D, 3D, AR & VR
Flexible	X		X	X		X

2 RESULTS

Recently, the implementation of the simulator was carried out in the class of Supply Chain . A test of previous knowledge was applied so that, once the run is finished, we can compare the results based on two variables: learning before (B MxREP) and after (A MxREP) running the simulation, all this through an analysis of experiments. A sample of 31 students was considered, and the data obtained by our survey is shown in Table 2:

Table 2. Descriptive statistics

Descriptive Statistics									
Variable	N	Mean	Standard error	Standard deviation	Minimum	Q1	Median	Q3	Maximum
A MxREV	31	58,60	1,63	9,06	37,59	51,86	59,82	66,9	79,91
D MxREV	31	92,90	0,876	4,878	87,5	90	100	97,5	100

The mean grades obtained before the activity in the simulator was 58.60 and the mean grades after the activity increased to 92.90. Furthermore, It can be seen a large difference between the maximum and minimum ratings obtained; before performing the activity the minimum grade was 37.59 and this value increased to 87.5.

A student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed.

The hypothesis to be checked is that the average of the grades obtained in the exams, which for the study will be called "knowledge gain", is different between the two exams.

H0: μ1=μ2 The application of the simulator does not make a significant difference in learning.

H1: μ1≠μ2 The application of the simulator makes a significant difference in learning.

where:

- μ1 is the population mean before the simulation.
- μ2 is the population mean after the simulation.

It is desired to reject the hypothesis Null H0, which will be able to demonstrate the veracity of H1 and validate the assumption that students improve their academic performance using the simulator in industrial engineering topics.

With the support of Minitab software, a student's t-test with two paired samples was done to validate that there is a significant increase in student learning when using the simulator, that is, the research protocol has been followed. The results are shown in Table 3.

Table 3. T Test

Test	
T value	P-value
-21.91	0.000

In addition to the results presented above, non-quantifiable differences in the performance of this activity could be observed. It was possible to see the clear participation of all the students, even in some of the teams there were discussions about what was the best strategy to obtain the greatest benefits. Despite the fact that their involvement was noted, it was observed that they treated this activity as if it were another one, that is, there was a lack of emotion, which arrived at the moment of explaining how they would do the same activity but through the simulator.

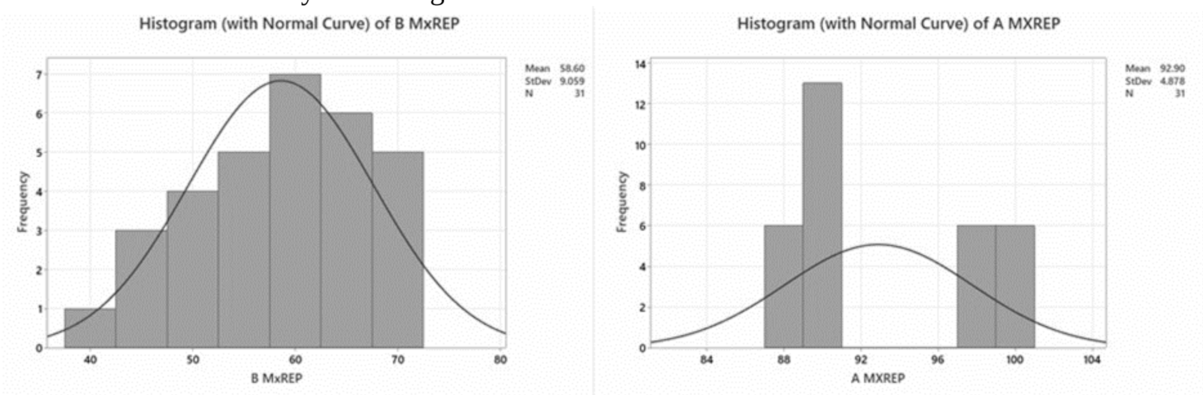

Figure 3. Boxplot before and after applying the simulator

3 CONCLUSIONS

The hypothesis regarding the use of simulators, in this case, the MxREP increased the learning in the logistics process was demonstrated. The variables under research were learning performance, engagement and competencies development, The use of simulators allow the student to emulate the reality under a controlled environment, and play different situations, from quality problems in the process and suppliers, until customs issues or last mile constraints. If a simulator does not get engaged with students immediately, we will lose interest in the learning process, but researchers don't necessarily lose the focus in that the activity is a medium to get an increase in the performance of the students, and the disciplinaries competencies development.

The advantage of MxREP is the flexibility to introduce any kind of product, the visualization of row material and the design of the whole supply chain of the product, the analysis start when the customer placed the CO and finish in the moment that is received the final product, we will measure every event in this process in order to improve the target.

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HUMANISING THE PRODUCT-SERVICE SYSTEM WITHIN A CIRCULAR ECONOMY FOR PRODUCT DESIGN AND ENGINEERING STUDENTS

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ABSTRACT
How do we avoid designing in the abstraction of organisational charts and system diagrams populated by text, symbols and icons to design for people, communities and the planet? To address this question, this paper discusses the integration of service design methods within a circular design process that encourages circularity thinking within product-service projects and enables students to: identify and communicate design opportunities from design ethnographic research; explore design opportunities as value propositions; identify and share the core values and proposed benefits of circular design opportunities; and to develop and present product-service concepts. Reflecting on product design engineering teaching practice within the context of current thinking in circular design and the circular economy, this paper presents an alternative perspective on visualising service-user journeys, stakeholder relationships and design propositions to enable design students to identify and explore innovative design propositions to circular design problems.

Keywords: Service design, product design, circular economy, circularity thinking, product-service-system, tools and methods

1 INTRODUCTION
Designing for a circular economy introduces complex networks, collaborations, and relationships into the context of product design. Increasingly, the context within which young undergraduate and postgraduate students of product design and engineering are designing is represented not only by the customer or the user of their products, but also includes a wide range of stakeholders, services, and systems. As the design process expands from techno-centric and user-centric to include and reference the wider context of designing for people and communities within complex product, service, system, and environmental relationships of a circular economy, it becomes increasingly challenging for product design and engineering students to cope with and design within a more holistic and complex product-service-ecosystem. How do we avoid designing in the abstraction of system diagrams and stakeholder maps to design for people, communities and the planet? How do we humanise the systems while designing for the planet and a circular economy?

The multidisciplinary nature of designing for a circular economy requires product designers and engineers to investigate, understand and communicate a wide range of stakeholder relationships and interactions when developing their design propositions, building empathy and trust. Service design tools such as stakeholder and service ecology mapping visualise actor networks and product-service ecosystems; their relationships, interactions and behaviours, bringing the systems and actors to life. Service journey maps record observational research and can be used as analytical tools to build insights and visualise the key value propositions of the product-service design. Service blueprints visualise how different product-service pathways interact across time. Integrating these methods and tools into the product design process helps the product design engineering students see and communicate key insights from their research to share and communicate the circular value propositions offered by the design.

Reflecting on the work with postgraduate Product Design Engineering (PDE) MSc students has brought a new awareness and insights into the value of service design tools and methods when teaching design process to students from a range of undergraduate backgrounds. Typically, our students come from undergraduate backgrounds in mechanical, electrical and electronic, production and manufacturing, and chemical engineering, as well as industrial and product design, applied mathematics and physics. Introducing service design tools and methods within a product design process has helped students research, identify, recognise, and understand who they are designing for as well as the wider context within which they are designing.

2 PRODUCT SERVICE SYSTEMS AND THE CIRCULAR ECONOMY

When designing for sustainability, we have considered the social, economic and environmental context within which we are designing; considering efficient use of raw materials, aiming to reduce energy and waste in processing, manufacturing, transportation and use. Benefitting the environment and reducing impact on the planet, while still enabling companies to make a profit, pay fair wages, reduce costs in the supply chain and to consumers, while improving the local and global economy. Moving to a circular economy, the focus has evolved to reduce, reuse, repair, recycle resources and regenerating natural systems, placing the planet at the centre of the design process. Due to the complex nature of the systems involved it is easy to lose sight of people within these circular and regenerative systems. Service design offers tools with which we can make sense of complex systems, while keeping sight of the people (citizens, communities, stakeholders) involved.

The principles of a Circular Economy [1] state that we should: design out waste and pollution; keep products and materials in use for as long as possible; and regenerate natural systems. Designing a product for a circular economy context, we are faced not only by the relationships between people and the product, but also by the service that may support, deliver, or be delivered by or through the product. To design for use, maintenance, repair and reuse of a product requires more complex relationships to be considered in the life cycle of the product. Maintaining sight of the people we are designing for becomes increasingly difficult with end-users and key stakeholders being obscured within organisational charts and diagrams. When it is difficult for the designer to understand the relationships between the key people and organisations involved from the diagrams, then it is difficult to empathise with the needs and requirements of these stakeholders and identify innovative design solutions. Typically, in that situation a design student will end up designing within their own limited experience and place themselves at risk of designing a product that is inappropriate or misses an opportunity to resolve an interesting problem. Many product-service systems developed by students under the context of a circular economy to share or lease products are not automatically more planet friendly as they can encourage increased consumption and production by providing more people access to more products [2] – they are disguising a more linear take, make, use, dispose model, although here the use cycle may be extended across more service users, and the recycle/dispose cycle appears to be controlled by the service provider. Recognising the stakeholder relationships can help students identify where the circularity of a design can be improved.

Where approximately 80% of the environmental impact of a product is committed at the design phase, it makes sense to introduce product-service system and circularity thinking to product design engineering students early in their career to potentially improve the circular economy credentials of future products. Within product-service design and development, product designers and design engineers will work with a wide range of stakeholders within the organisation as well as out with the organisation [3]. It is recognising the interactions and relationships between these stakeholders where service design tools can help.

2.1 Borrowing from Service Design

Service design consultancies such as LiveWork and Engine in the UK have long recognised the need to see the people engaged with services and to understand the 'highly complicated networks of relationships between people inside and outside the service organisation' [4]. Borrowing from systems and actor network theories, service designers developed journey-maps, relationship maps and service blueprints to bring service ecosystems to life, capturing and communicating insights from research and observations, visualising people and their relationships within the service ecology. Early on, educators in product design and engineering recognised the value of service design and product-service-system methods to help students more deeply understand and empathise with the people they are designing for and design more appropriate product-service solutions [5], [6], [7]. The integration of service design methods and tools within a circular design process enables students to identify and communicate design opportunities from design ethnographic research, explore design opportunities as value propositions, identify and share the core values and proposed benefits of circular design opportunities, and to develop and present innovative product-service concepts. As illustrated in Figure 1, it is important that the people observed through research are shown and represented within the service journeys, service ecology and stakeholder relationship maps, rather than by representing them with clipart and icons – so much information relating to activities, interactions and context is lost by doing so, and reduces the ability of the designers, and their audience, to build empathy with the people involved, their needs and requirements. When mapping the various relationships and interactions as a service blueprint, the various products and infrastructure that support the service-system are represented below the 'line of visibility' or 'back-stage.' For the stakeholder relationship map, the details of touchpoints and products supporting the service occupy the outer circles of the relationship map. It can be thought of as taking the service journey blueprint and distorting it into a flattened cone, where the service user journey is around the centre of the cone and the individual touchpoints and details that were at the bottom of the blueprint are now seen around the periphery if the flattened cone. This idea is developed further in Figure 4 where the circular design concept is seen at the centre and the product components are expressed around the circumference to identify and explore the ecosystems of circularity within the design project.

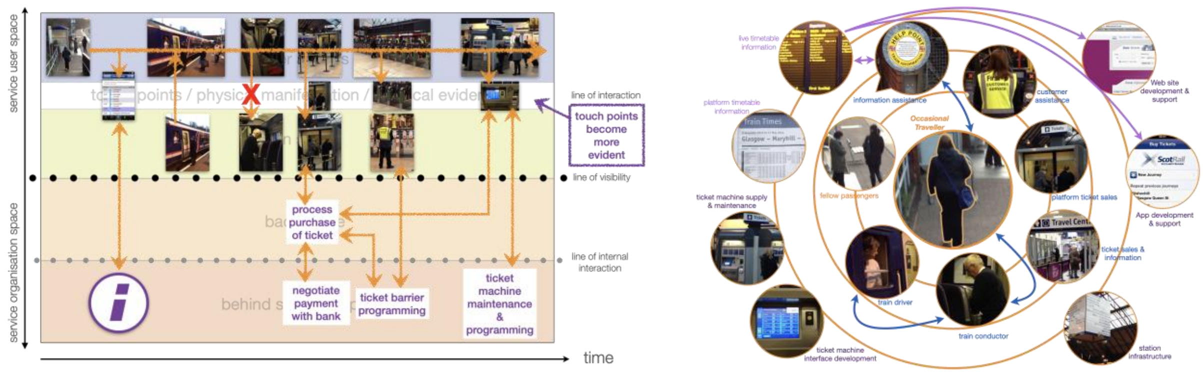

Figure 1. Mapping service journey/service blueprint < > stakeholder relationships

The importance of visualising the relationships is key to sharing information across multiple disciplines and stakeholders. For large groups of people, communities, organisations, etc., personas may be generated from within the stakeholders involved to ensure that as many people's needs and requirements are represented. However, this does not mean that the personas are simply made up - people reading or being presented with the design research and propositions should be able to recognise their own needs and requirements represented within one, or more personas. Sharing information visually facilitates collaborative sensemaking and collective decision-making within teams and across organisations.

2.2 Borrowing from Circular Design

The Ellen MacArthur Foundation Butterfly Diagram [8] visualises the circular economy by representing material flow within the two main cycles of the biological cycle and the technical cycle. The RSA Great Recovery project [9] generated four design models from the technical cycle to represent Design for Longevity, Design for Service, Design for Re-use in Manufacture, and Design for Material Recovery, as shown in Figure 2. In a circular design context, product design would consider design for longevity and service, while also being aware of the need to design for repair and reuse with consideration of material choice to aid material recovery.

How consumers become emotionally attached to a product and how they behave with regards to looking after the product, maintaining and repairing it will affect the longevity of the product. A consumer's need for ownership and reluctance to lease, share or re-use products is also likely to require some behavioural and attitude change if they are to embrace a more circular approach to product use [10], [11]. It is within this context especially where visualising the people involved within the circular design process enables the designers to empathise with them, understand their needs, requirements and behaviours, thus enabling them to design more appropriate products for people *and* the planet.

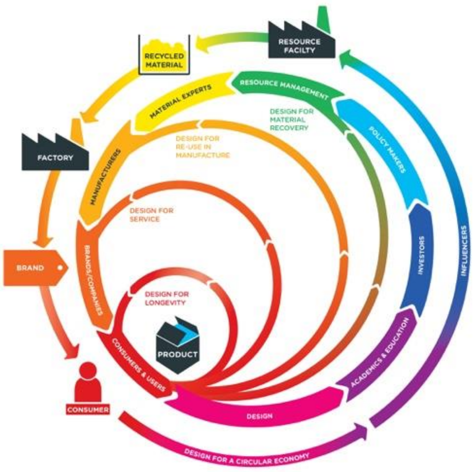

Figure 2. Four Design Models for Circular Economy. (Credit: RSA The Great Recovery)

3 HUMANISING THE SYSTEM

Getting out into the field to observe and experience how people behave requires some design ethnography skills, but more importantly observation and curiosity – curiosity not to settle for what you first saw, but to continue to observe and ask questions to understand and infer what underlying core issues led to what you saw. Combining first-hand observations with secondary research can place your observation findings within a larger social-political context. Extracting insights from the research and mapping out the information gathered for an identified topic or design opportunity, enables students to map out from the central topic to explore the insights into the design problem, identify the people and stakeholders involved within a specific context, and to generate 'what if' design propositions, Figure 3. By mapping out the design propositions along with all insights, people and context, it easier for the students to explore alternative what if propositions from the data presented on the propositions map.

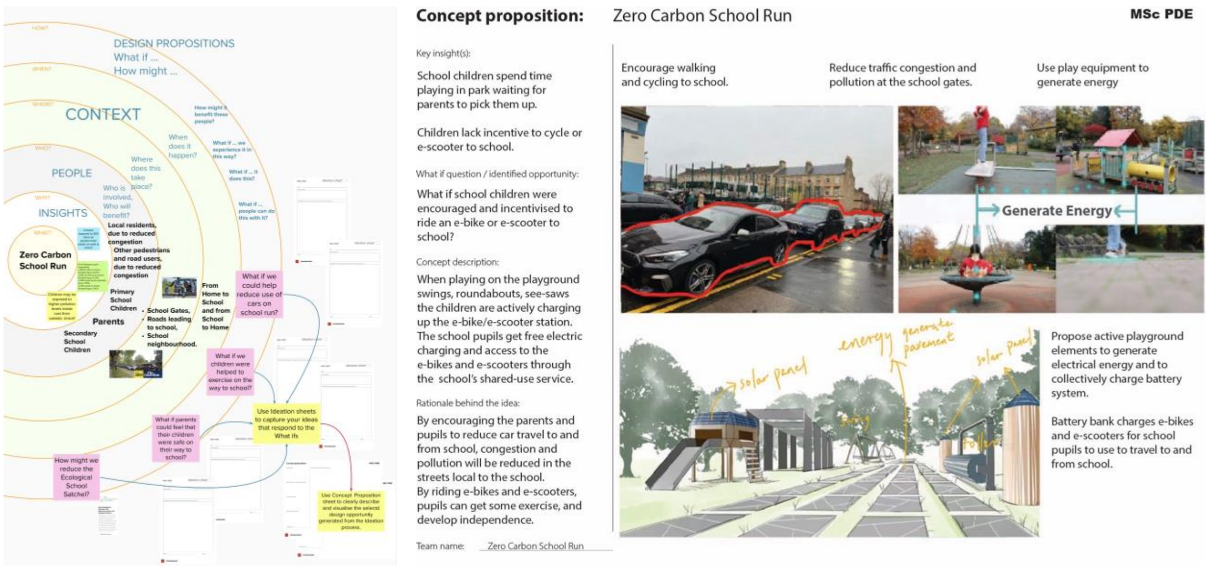

Figure 3. Identifying Opportunities > Generating Design Propositions

As shown previously in Figure 1, the service-user journey/blueprint can be used as an analytical tool to extract the relevant stakeholder relationships and to understand the interactions, transactions and negotiations between people and organisations. These stakeholder relationships can be used in conjunction with the four design models shown in Figure 2 to determine where opportunities might be found to improve the circularity of the product [12], [13]. The design proposition and relationship maps can then be used to zoom out and explore the wider context of a problem, or to zoom in and consider the details. For example, as illustrated in Figure 4, the circular economy topic is placed at the centre, similar to that shown in the proposition map in Figure 3. We can then explore in increasing concentric circles: the people, stakeholders and organisations involved in the circular design; the product-service that delivers the design; the products of the service; and in the outer circle the components that make up the product. By applying circularity thinking [14], zooming in and out and switching perspective from planet to components we can then explore the ecosystems of circularity within our design. By considering each level from a circular economy perspective, each circle will carry the circular design principles of the previous circle just as fractals carry the information of the larger organism within nature.

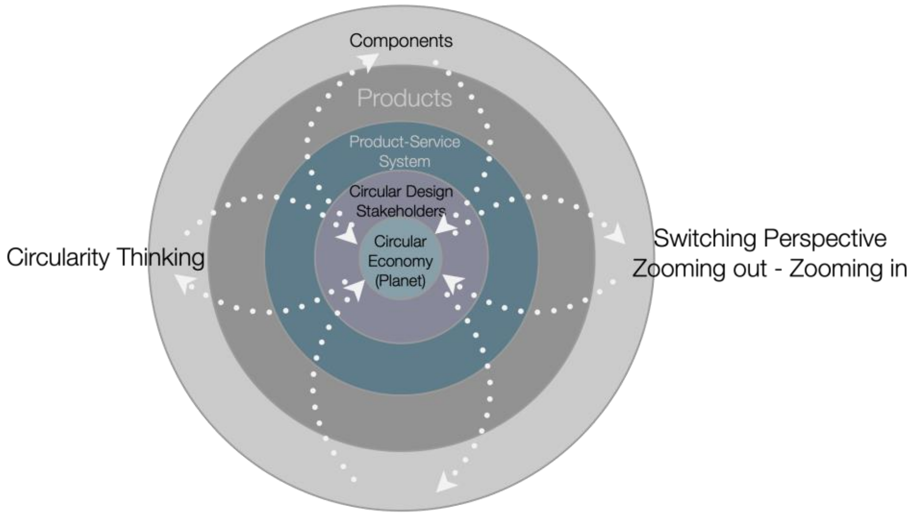

Figure 4. Mapping ecosystems of circularity

4 CONCLUSIONS

Presenting students with open project briefs, rather than prescribed closed ones, has encouraged them develop design ethnography skills, and provides them with the skills and confidence to go out and engage with people to learn more about the core issues people experience, and to understand their needs, desires, requirements, and behaviours. Students are then better equipped to generate insights that lead to innovative design solutions, and by incorporating circular design thinking, the product design solutions will be more appropriate to the planet as well as to its inhabitants. By considering the planet (or appropriate elements of the environment) as a ‘persona’ we can change our perspective on a problem to see alternative design solutions [15]. For example, when students in a service design workshop were considering food waste, they found it difficult to determine the best course of action when considering the problem from the consumer’s perspective until they looked at the problem from the vegetable’s point-of-view. They had identified that by sorting out the ugly and misshapen vegetables and fruit, supermarkets were contributing greatly to food waste. When the students considered the effect of this ‘beauty pageant’ from the perspective of the fruit and vegetables, they were able to then create more innovative design solutions to reduce food waste. Designing with circular-based personas, rather than make-use-dispose, single-use personas, helps us to keep in mind the circular design principles that we are trying to achieve [16].

The benefits we have observed from introducing this approach to PDE postgraduate students have been that the students:

- Better understood the wider socio-economic context that they were designing within.
- Were able to make sense of complexity and identify design opportunities by using service design tools such as service journeys, blueprints, relationship mapping and personas.
- Developed their ability to visualise and design for multiple actors and interactions within a product-service system.
- Using service design tools facilitated collaborative design practices across their design and engineering disciplines.
- By adapting service design and human-centred design methods to circular design thinking, they were better equipped to tackle problems within a circular economy context and apply a more planet-centred design approach.

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WHAT IF XR IS FULLY UTILISED IN DESIGN EDUCATION? PRELIMINARY RESULTS FROM A PARTICIPATORY DESIGN FICTION STUDY

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ABSTRACT
Combining Design Fiction with participatory design principles has been shown to improve the role of participants, from research subjects to research partners. By supporting the process with futuristic and strategic thinking tools, participants can become experts in their own experience. This research project explores how Extended Reality technologies can be integrated as a design tool in design education. In this paper, a methodology of using participatory design fiction to engage design students in speculating the future of design education in the context of emerging technologies is presented. A three-part workshop was conducted, which involved 68 Design MSc students. A total of 17 "actionable" future scenarios of design education in the context of emerging technologies were proposed at the end of the workshop. This paper focuses on one of the workshop activities, Sequential Backcasting and What If cards, and provided a preliminary thematic analysis of the results. This study contributes to the development of participatory design methodologies and offers insights into the potential role of Extended Reality technologies in design education.

Keywords: Design fiction, participatory design, design education, immersive simulation, extended reality technologies

1 INTRODUCTION
Design fiction (DF) enables designers and researchers to create speculative narratives and artefacts to explore potential futures. However, it requires specific skills and academic credentials [1]. Participatory and co-design involve individuals most affected by future technologies in shaping outcomes [2]. Participatory Design Fiction (PDF) and co-design studies are most effective when participants are treated as "experts" in their own experiences and research partners [3], [4]. This literature survey examines how participants' focus, diversity, and design method knowledge impact their involvement in DF studies. We also provide relevant research for context, focusing on co-design and PDF studies that engage users, stakeholders, and communities, specifically in educational and technology-future domains. In co-design research, marginalized users were provided with a safe and engaging space to share their experiences. Tsekleves [4] used co-design to define problems, develop DF scenarios with stakeholders, prototype, and test. Affinity mapping, small group discussions, and engagement with older citizens were utilized in two co-design workshops. Participatory design, user-centred design, and science fiction inspired and illuminated the values and imaginaries of vulnerable patients. Participatory design and co-design, within the DF framework, involve individuals most impacted by future technologies.
PDF enables public technology speculation. DF scenarios and guiding questions sparked discussions in multiple studies [5], [7]. Simplification of DF activities for the public is crucial, using short, simple, and relatable questions to encourage creative repurposing of existing technologies instead of inventing new devices [5]. These studies require active participation and facilitation. PDF scenarios are shaped by diverse stakeholders, including local policymakers, entrepreneurs, activists, academics, and graduate students participating in co-design workshops to brainstorm new uses of digital technology in public spaces [3]. Professionals and postgraduate students were the only multi-stakeholders [6] and [7]. Angheloiu [6] explored sustainable social innovation through speculative design and foresight.
Stimulus toolkits were used to study PDFs, and Mixed Reality Immersive DF and VR Immersive DF were employed [7]. These studies demonstrate the potential of PDF to engage diverse stakeholders in

envisioning future scenarios. Rapp [8] conducted a multi-year study involving psychology students without design or HCI backgrounds, using DF in higher education. The authors guided students in critically evaluating technology through traditional design phases and DF methods. Design students also explored DF [10, 11]. In [9], researchers addressed challenges related to emerging technology design and speculation, focusing on human skills to overcome technological dependency. Industrial design students were tasked with choreographing design challenges for emerging technologies. The second challenge involved technology-enhanced design creativity. In [10], 80 service design master students utilized DF methods and strategic thinking to promote divergent thinking about alternative futures and counter three pessimistic visions. Storytelling and music served as inspirations. Psychologists and designers have participated in DF studies, considering technological dependency and creative potential when designing and speculating about emerging technologies. DF and multidisciplinary methods effectively engage stakeholders in future speculation. However, design students rarely engage in speculation about new technologies and sustainable futures. This study addresses this gap by utilizing design students as "experts" to analyse and propose actionable DF scenarios, encouraging critical evaluation of their roles as designers and co-creators of design education futures.

2 METHODS

2.1 Phase 1: A pre-study: Expert Interviews

The preliminary investigation included semi-structured interviews with 24 design educators from six nations. The participants were academics and researchers in design and related fields, who are currently engaged in higher education and/or academic research, and who are familiar with XR and related technologies through research and/or education, preferably with practical experience. After completing an online screening questionnaire, experts were asked to participate in a one-hour online semi-structured interview. Each expert was tasked with reflecting critically on a brief future scenario in which XR is fully integrated as a design tool in design studios and discussing the broader implications for design education.

2.2 Phase 2: Extracting Future Scenarios

Future scenarios were identified by deductive and inductively analysing interview data. The scenarios were selected based on impact and uncertainty to avoid bias. Researchers and practitioners can bias scenarios [11]. The authors followed Woody Wade's (2012) approach by plotting the scenarios along the two axes of impact and uncertainty: predetermined elements, secondary elements, and highly impactful, highly uncertain elements (Figure 1). Scenarios with predetermined elements did not fit the stimulus toolkit's goal of creating realistic fictional worlds [11]. For example, XR providing immersive and interactive 3D elements in design studios was predetermined by academic literature and knowledge. The least impactful scenarios have been eliminated, regardless of uncertainty. The filtering process yielded 17 highly impactful, highly uncertain "What IF" statements that balanced utopian and dystopian scenarios.

2.3 Phase 3: Designing a PDF Stimulus Toolkit

A stimulus toolkit was developed from DF scenarios for use in PDF workshop sessions. The activities were designed to guide design students from a familiar to an unfamiliar context, progressively building their design thinking skills. The first activity only required basic design thinking skills, while the second activity combined design thinking with futuristic thinking and the third on added strategic thinking. An XR immersion session was included between the second and third activities. At the end of the workshop, the participants presented their final proposal of future actionable scenarios.

2.4 Phase 4: Identifying, Approaching and Recruiting Participants

The workshop execution plan was aligned with the start of the Design Futures module at Brunel University London. The study participants consisted of 68 Design MSc students, divided into three groups. Participation is voluntary, and participants were given sufficient time and the option to freely decide whether to participate.

2.5 Phase 5: Introducing Design Fiction (1 hour)

Designed as a part of their module weekly sessions, the students attended an introductory lecture on DF. The lecture started with defining DF and its relationship with other terminologies such as critical design, design for debate, design futures, discursive design and speculative design. As the students are from the design discipline, the difference between “traditional design” and speculative design had been explained. Then, the presenter introduced DF tools and methods by focusing on the most relevant to the coming workshop activities which are, Cover story or tomorrow’s headline, immersive DF, Backcasting, What If and Future Cone. The focus was on explaining the method of Backcasting as the participants' knowledge of this method will be required to complete the main activity in the workshop. Recent examples had been discussed such as “The World We Made” book by Jonathon Porritt and the Galwad movie. The lecture ended by defining XR technologies in the context of the study so the researchers and the participants will move on from the same ground when doing the workshop activities. For this study, XR had been used as the umbrella term for AR, MR, and VR.

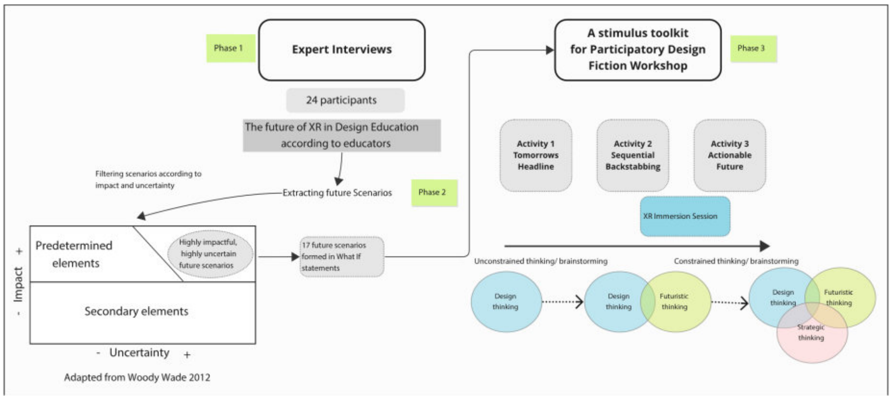

Figure 1. Study Framework

2.6 Phase 6: The Workshop (2 hours X 3)

The duration of each workshop session was two hours. The workshop had been repeated three times. The workshop started with reviewing the main concepts learned in the introductory lecture and then distributing Participants' Information Sheets and Consent forms. After reaching an agreement to take a part, activities began.

2.6.1 Activity 1: The Unbiased Design Futures Magazine (15 minutes)

The first activity aimed to stimulate brainstorming and discussion about the future of design education without bringing emerging technologies. It adopted the cover story or tomorrow’s headline brainstorming game where players pretend to be journalists for a fictional magazine "The Design Futures" 20 years from now. Participants were asked to report and sketch about a future trigger for change that will have a powerful impact on design education.

2.6.2 Activity 2: Sequential Backcasting & What If Cards (35 minutes)

The second activity combined design thinking with futuristic thinking. Each sub-group (3-5 students) had been given a What If a card containing one of the 17 DF scenarios. The activity was designed with inspiration from the six steps of Backcasting identified by Robinson (1990). According to Robinson, Backcasting is ‘*an approach to futures studies which involved the development of normative scenarios aimed at exploring the feasibility and implications of achieving certain desired endpoints, in contrast to forecasting studies aimed at providing the most likely projection of future conditions* [12]. Backcasting could give DF studies the kind of big-picture, all-encompassing view that is missing from DF. In this study, the authors took Backcasting methods one step further by using a new method called sequential Backcasting. In sequential Backcasting, the development towards one specific expected scenario is divided into a sequence of phases and we then find one logical path from where we are today to that expected scenario [14]. The participants had to place themselves in three phases, *a)2043*: participants started by placing themselves in the future in 2043 and they analysed the What If scenario according to its pros, cons, and concerns. *b) 2023:* After undertaking scenario analysis, they described the present situation in relation to the What If scenario. The present situation was analysed according to four perspectives explained in the results section. *c) 2033:* This is the intermediate phase where they had to think about critical milestones such as potential big events that will extremely accelerate or motivate the actualisation of the DF scenario. *Phase triggers:* participants had to identify triggers needed at present to reach the critical millstone/s or the intermediate phase. Then, they had to identify triggers needed from the intermediate phase to reach the final scene.

2.6.3 Immersion Session (35 minutes)

The immersion session aimed to provide ethnographic experiential futures which could lead to a more understanding of the potential of XR technologies in the design process and stimulate critical discussion about the future of design education. The participants experimented with four XR scenarios: integrating Augmented Reality tools, specifically Adobe Aero, in the current design process, 360 videos to empathise with the human of the future, interacting with 3D objects in Mixed Reality (using HoloLens 2 device), and sketching concepts using Gravity Sketch in VR (using Meta Quest 2 headset and controllers). During their experiments with the various XR technologies, participants were highly engaged. They asked questions and were involved in critical discussions regarding the advantages and disadvantages of XR in their current design process. Even after the immersion session had concluded, participants continued to take turns in experimenting with the devices while completing the remaining workshop activities.

2.6.4 Activity 3: Our Actionable Future of Design Education & XR (15 minutes)

The third activity integrated design, futuristic, and strategic thinking. Participants were asked to envision an actionable future of design education using XR technologies by answering guidance questions. In the end, participants presented their proposed "actionable" scenarios to the group.

2.7 Phase 7: Developing a Final Scenario

A final scenario of the future of design education will be developed according to the collected data by answering the question: What might the impact of XR technologies be if their potential is fully utilised in Design Education?

3 RESULTS

During the workshop sessions, 17 DF scenarios were analysed, and another 17 "actionable" future scenarios were proposed. The students demonstrated high levels of engagement and collaborated extensively to complete the assigned tasks. The preliminary results of the second activity were reported only. This paper presented overall data by answering a possible DF scenario: What if XR is fully utilised in Design Education? To answer the overall question, only broad themes from the collected data have been extracted. Pros, cons, and concerns of fully utilising XR in design education are shown in Table 1.

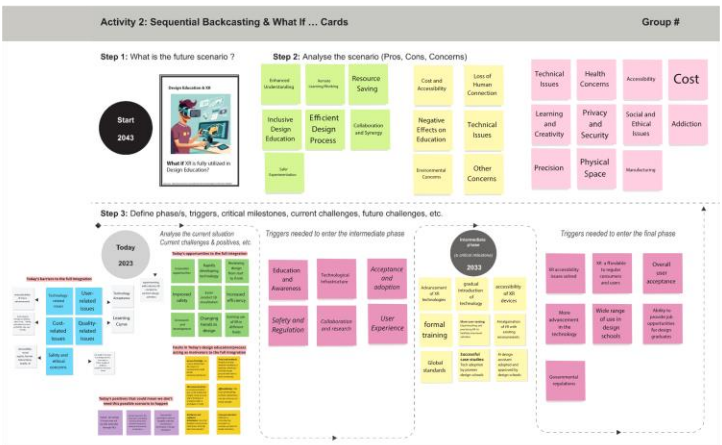

Figure 1. Preliminary results from activity 2

3.1 2023: Analysing the present Design Education (in relation to the future scenario)

After analysing the future scenarios, participants returned to the present and examined design education in relation to emerging technologies from four perspectives: Today's barriers to full integration, today's opportunities to full integration, faults in today's design education/process acting as motivators to the full integration and today's positives that could mean we don't need this possible scenario to happen. All extracted themes are presented in Figure 3.

Table 1. Pros, cons, and concerns of full integration XR in Design Education

What if XR is Fully Utilised in Design Education?		
Pros	Cons	Concerns
• XR technology's immersion feature has the potential to improve the comprehension of design concepts. • Exposing design students to immersive virtual user scenarios could provide them with realistic and detailed insights about user needs and perspectives, resulting in more empathic and effective design solutions. • The ability of XR technology to make learning and working more flexible and accessible. • With the advancement of the metaverse and social VR concepts, it is anticipated that global student collaboration will benefit. Participants anticipated that this degree of collaboration will enhance design synergy. This could lead to inclusive design education in which XR is used to expand design education to underprivileged students and communities. • Resource conservation: Participants considered how using XR as a tool for design could save time, energy, and overall resources. • The integration will make extermination safer because students will be able to experience dangerous or unpleasant situations to comprehend users.	• Accessibility to XR may be an issue. According to [13], XR platforms have significant hardware and software accessibility issues that must be resolved. • Participants identified cost and device usability as additional obstacles. • XR can limit face-to-face interaction, thereby diminishing opportunities to form real-world social bonds. • XR technologies in design education can also be hindered by negative effects on education, technical issues such as device breakdowns, power and connectivity issues, and software errors, as well as environmental concerns such as a lack of resources and an increase in carbon dioxide emissions.	• Technical, health-related, and accessibility concerns predominate in XR technologies. • Among the technical concerns mentioned are bugs, dependability, safety, and the hardware learning curve. • Vision, headaches, the senses, and a sedentary lifestyle are causes for concern. Accessibility concerns are primarily driven by the expense of the technologies. • Could XR be a source of distraction, and what is its impact on the creativity of students? • Concerns such as privacy, security, and social and ethical issues are applied to the context of design education from other general contexts. • Concerns regarding the use of XR for manufacturing in the design process and how this could affect the precision and accuracy of the final prototype.

3.2 2033: Critical Milestones to Achieve

Several milestones must be met by 2033 to fully integrate XR technologies into design education. These milestones are organised into actionable themes in Figure 3.

3.3 Triggers Needed Now & Triggers Needed in 10 Years

While we cannot predict the future, we can work to create conditions that increase the likelihood of a positive outcome [13]. Several immediate triggers are needed now and in 10 years to achieve critical milestones in fully utilising XR in design education. Examples of triggers needed now to motivate the full integration of XR in Design Education are, educating design students on XR technologies' capabilities, promoting its value, sensitising the public to its effects, raising awareness through XR training and experimentation and including safety triggers and regulations that must be addressed before the full integration. This includes virtual and real-world boundaries, a good management system, safe AI, and supervision to fix AI errors and improving user experience by focusing on graphics, resolution, and design process engagement. In ten years, other triggers are needed such as, having successful case studies of using XR in the design process in top design schools and overcoming XR accessibility issues for a wider adoption in higher education institutions.

4 CONCLUSION AND FUTURE WORK

This study proposed a systematic approach to planning and structuring a DF study in higher education context. It aimed to actively engage design students as experts in speculating the future of design education in relation to using XR as a design tool. Although the educational impact of the present systematic approach was not intended to be evaluated or measured, we argue that design students' participation in futuristic debates on emerging technologies would make students consider the consequences of their design choices and help them become experts in their own experience. In addition, being engaged in immersion sessions where XR is used as a design tool can help design students imagine future scenarios and workflows. After analysing all findings, a final scenario will be proposed about the use of XR and related emerging technologies as a design tool in design education.

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(RE) NAMING THE PEOPLE AT THE CENTRE OF DESIGN PROCESS

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ABSTRACT
While design methodology can be applied to ever-wider problems, 'people' remain the centre of design's focus. In this evolving landscape, it remains relevant to question which words should be used to refer to these people. While a wide range of words exist, each one can potentially influence or limit the way people are considered and are present in design process. Different terms suggest different levels of participation by those concerned, in an evolving context where more active roles are sought for the people concerned by design interventions. This paper discusses chronologies of accepted terminology for different people involved in design processes and highlights recent evolutions and debates around certain words. Based on literature reviews and in-depth interviews with design practitioners and researchers, seven issues around user/people terminology are identified and could constitute a basis for further research. This discussion paper aims to confront ambiguities and encourage considering appropriate, responsible language use in evolving design process. (Re)naming the people at the heart of design methodology has ethical implications and is particularly relevant in the design education context, influencing the status given to people involved in future design activity.

Keywords: User research, human-centred design, design for sustainability, participative design, design terminology

1 INTRODUCTION: ARE YOU A USER?

Fifteen years ago, Sanders and Stappers [1] wrote about "the person formerly known as the 'user'". Ten years later, a special issue of the magazine Occula on "The place of the user in design" is introduced [2] by *« Usager »: un terme inconfortable*. "User: an uncomfortable term". The introduction continues by pointing out that the term 'user' is used by convention, despite being criticised by human science and design communities. Yet today, some of the fastest evolving parts of the design field contain the word "user" or at least "U" in their very titles. Within the rapidly growing UX/UI area, actors in the field [3] suggest that due to the fact that professionals in this area come from ever wider variety of backgrounds, the glossary of terms used might need to be revisited once a year. Beyond the fact that "confusion about terminology can disrupt projects" [3] it is important for designers to be able to define, describe and communicate what they do, with words that will not generate confusion. Within the UX field, with the job title 'user experience' designer increasingly becoming "product designer", it may be relevant to question the words used for the people on the receiving end of this 'product' design.

The need for carefully chosen terminology also increases as the design process becomes more participative. In current design practice the people being designed for take, in reality, a wide range of roles in the design process [2] and the way we name a user is already attributing her or him a particular role in the (design) project. Approaches and terminology need to reflect this evolving status of non-designer participants and be respectful of their input [4]. In this changing landscape the question of how designers view the people they are designing for [5] may also be raised. The language used can have an impact on their relationship and help to avoid a form of "us" (experts, researchers, designers) and "them" position which may be increasingly less relevant. This relationship and related designer mindset and posture is already being widely questioned in Design for Sustainability: in Social Innovation and Systemic and Transition design approaches [6] [7] the focus is on lifestyles and actively equipping communities to be the on-going (re)designers of their environment.

The aim of this discussion paper is to (start to) explore these emerging issues and ambiguities and encourage considering the most relevant terms for more respectful, responsible language use in our evolving design process. Questioning the most relevant ways of naming the people at the heart of design methodology has important ethical implications and is particularly relevant in the context of design education, influencing the status given to people involved in future design activity.

2 CONSUMPTIONS TO EMPOWERMENT

To contextualise the questions raised in this article we briefly present some of the strands of the history of user-centred design and of the words used to describe the people at the receiving end of this professional activity. The history of research for understanding people's lives by first hand and in-context observation can be linked to the discipline of anthropology, which continues to influence and contribute to design methodology. This study of the human may be traced back to Ancient Greece but is a named discipline from the 1700s [8]. The branch of anthropology most influential for design, human/social anthropology, is established in the early 20th century. Today emerging post-humanist ethnography [9] approaches continue to inform design research and practice.

Design's concern for social issues has roots before the 20th century, but these issues were not necessarily seen as central. Design pioneer Henry Cole saw his teapot design as more representative of good design than an educational children's game he designed and commercialised in the same period [10]. Despite 19th century figures such as Catherine Beecher and William Morris addressing the quality of domestic environments and improvements in people's daily life [11], the First Things First manifesto in 1963/64 [12], (reiterated [13] at the end of the 20th century), illustrate ongoing frustration in the design community that design is not more concerned with real life and social issues.

The history of professional design activity integrating people's needs might be traced back to Henry Dreyfus, and 'designing for people'. Dreyfus bemoans clients in the 1930s only wanting him to make things more attractive for the 'consumer'. His own design approach is informed by observation of details of 'people's' lives (see publisher's preface)[14], whilst also mentioning 'human engineering': "our job is to make Joe and Josephine compatible with their environment". Despite a focus on peoples' behaviours, Dreyfus generalised from these to produce standardised solutions that might "affect the lives of millions of people". While focused on 'people', the approach was one of turning human factor data into universal body types to inform large scale design [15]. Sometimes cited as the origin of Human Centred Design, the work of Herbert Simon (Sciences of the Artificial) may also be concerned with understanding/controlling human behaviour rather than values of human dignity [16]. User-Centred Design and theorising the necessity of integrating user needs in all of design process can be traced back to the work of Donald Norman and also of Gould and Lewis [17] in the 1980s[18]. Towards the end of the last century user-centred design starts to shift beyond needs towards notions of emotion, pleasure and affect.

The history of participation in design [1] dates from the 1970s and the Scandinavian Collective Resource Approach involving workers to develop improvements in the workplace. In the first Conference on Design Participation, 1971, Nigel Cross introduces the need for "citizen participation in decision making…user participation in design" [1]. Co-design and participation have perhaps really become part of design process only in this century [19], leading to wider understanding and also questioning of issues surrounding participation[2][18].

We can therefore trace an evolution of the status of people we are designing for from "people encouraged to consume" in the 1930s, to real people (Dreyfus) in the 1950s, as citizens (1960s), their human behaviour, and their user needs (1980s), their emotions (1990s), their involvement, (2000s), and to their creativity and empowerment today.

Beyond this rapid overview of an evolving landscape, today growing attention is paid to those not directly concerned. The holistic approaches in current design practice, in the face of environmental challenges, increasingly take into account those who are not yet or will never be users. Deni & Cattoir [2] emphasize the need for changing focus (*"déplacement du regard"*) towards minority or extreme users and non-users, recognising that not all people have the same voice or capacity to participate. This widening of focus, which can be seen in systems-oriented design for example, highlights the need to include non-stakeholders in the overview of (mapped) systems [20] . Transition design [6] and "life-centred" approaches [21] involve considering non-users, "invisible humans" and also non-human entities such as other living organisms and also eco-systems. New design approaches suggest the need to moving beyond human-centred design [21][22] and consider 'more-than-humans' [18].

Evolutions in the design landscape bring the need to consider multiple actors and entities, beyond the "user" and even the human, and question how our terminology can respectfully address the growing range of roles taken by non-designers within design interventions.

3 METHODOLOGIES

A literature review was carried out to identify new terminology for the people concerned in design process, identify current research and discussions addressing issues of terminology and trace the evolution of terminology in design research literature, in particular in relation to emerging fields of design for sustainability (DfS).

In parallel to the literature review a series of exchanges with practitioners, educators and researchers in the design field were organised. 15 people in all from design research, practice and education contributed to this research, from six different countries (UK, US, France, German, Belgium and Japan), working in different languages. The design domains represented by the participants include UX (6 participants), Ergonomics, Product, Services, Strategy (1 participant), Social Innovation (1 participant), Furniture, Industry, Research and Education. The participants ranged from recent graduates to senior strategic design management level. In this article, where relevant each participant is referred to by a letter, and principle activities (UX, ID, P(product), SI(social innovation), ED (education and research)).The research aim was to identify most commonly used terminology, and also parts of the terminology that appear to generate problems and ambiguity. The initial question asked to all participants was "what do you call them?". Based on a free listing exercise, participants were asked to note all the terms for people/users they use or encounter in their design practice. They were asked to then add comments to the noted words and also mark those most used. Participants were able to answer in their own time. Participants were also given the option to comment and annotate an existing list of possible "user/people" words in English or French (six of the participants are based in France). Only four participants chose to comment the existing lists. In the case of most participants the cover letter/e-mail also included comments about the subject which constituted a non-intended but valuable supplementary source of analysable information. Following the listing exercise, written exchanges and/or in-depth on-line interviews were carried out with the majority of the participants.

For this first exploration of the subject it seemed valuable to exchange with designers working in the field of UX, both for the focus on the "users/people" in this field, but also as the terminology in this area may be the most affected by the diversity of professional backgrounds, and the rapid evolution of the discipline. For future research it would be valuable to aim for a more systematic representation of a wider range of design disciplines, in particular designers most directly related to emerging forms of DfS, but also with designers working in social innovation.

Just under half of the participants in this study are involved in design teaching and research. While the feedback from design researchers and educators provided useful insights, it is clearly important to keep in mind that terminology in research and education may not reflect the design industry as a whole.

In-depth interviews were not possible with all participants, but the research highlighted that both the in-depth interviews and written exchanges represented a form of correspondence and ongoing discussion. This notion of time, distance and exchange seems particularly relevant in this context, giving participants time to be sensitised to the questions and perhaps pay attention to things that might otherwise go unnoticed [23]. One participant mentioned that he had tried out new words following discussions around the subject, and another commented "*this is an interesting one [beneficiary] and came up on a recent project*". One interview included several members of the same design team, which created an interesting discussion generating reactions to suggestions made but would have been interesting to follow up with individual and written exchanges.

4 PEOPLE WORDS AND FRUSTRATIONS

Over 40 different user/people words were commented and/or proposed during the discussions with designers. The feedback from participants suggests that few terms are appreciated by all, and many terms generate both positive and negative reactions.

'Users', and related words (end user, *utilisateur, usager*…) generated a diversity of reactions from positive to negative, whilst being the terms most commonly used by most (but not all) participants. In both the French and Japanese languages two different words closely related to "user" are used in design process. The French *utilisateur* and *usager* suggest respectively people concerned by commercial/paying products and those using public/non-commercial services. In Japanese there is a similar distinction between:

利用者 (*riyosha*): someone who benefits from the use

使用者:(*shiyosha*) more general, someone who uses as a means to

These more specific user words seem to be better accepted, but perhaps more the ‘using as a means to’ than (the more passive) ‘benefitting from’.

Numerous frustrations were mentioned by participants around various terms used for people in the design process. These give (by opposition) an interesting indication of what qualities might be needed in future terminology: “*reduces relation to use act alone”, “lose notion of emotion”, ”lacks sense of agency/choice”, “too broad”, “not accurate enough”, “don’t feel comfortable using”, “use out of habit”,“anonymous”, “sounds media-oriented”, “sounds marketing”, “too binary, as if the user only has one facet”, “no longer has meaning”, “impersonal”, “inaccurate”, “has a marketing/business connotation”,“dehumanising”.* This list also highlights one of the noticeable points from participant replies, namely that commerce, marketing and consumption related terms are widely criticised.

As confirmation of the above point, the smaller number of positive attributes linked to people/user words in design give an idea of qualities the desired terminology could have: *“unique person, with own tastes, story”, “easy to throw around”, “non-specific”, “elevates someone”, “makes them interesting”, “encourages us to think about their needs and desires”, “underlines their singularity”, “puts them on the same level as experts”.*

Finally in this research we can note (provisionally) that there may be more dissatisfaction than satisfaction around the people/user terminology. This is a point that needs to be confirmed in future research and may be linked to methodology issues.

5 DISCUSSION AND NEW QUESTIONS

The participant replies and the literature review highlight the following issues that could be the object of a second phase of research around the evolution of people/user terminology in design.

The word “user” continues to be valuable, suggesting there still a need for a simple, non-specific term and the need for shorthand. The term ‘user’ emerged in 1970s - so is now 50 years old. Is this term now too focused on use alone? While most participants recognised that “user” or end user, or *utilisateur* (see previous section) was the most common term, these words also generated the most ambivalent comments and suggested a certain dissatisfaction. Interestingly the term “user” was also seen as beneficial because it was generic and easy to use “it’s non-specific” (D_ID/P), “it’s not about their taste, just how they use it” (C_ID/P). At the same time other participants found using the term uncomfortable, because they feel it to be “impersonal & dehumanising” (G_UX)

The need for precision was widely commented and terms such as end user, novice user, occasional user, primary user, indirect user and many more were highlighted. Equally, as a mark of respect for the people who are now much closer to the designer in design process, participants mentioned trying as much as possible to describe the person through what they do, and their job title and the actual job/task done by the people: operator, engineer, installers, visitors, attendants…“I always try to state the role of the end user we’re designing for” (G_UX). “We design for people who do specific work, so we call them by their job name” (P_ID). Adaptation across related design disciplines is also an issue mentioned - with participants mentioning their need to adapt depending on whether the discussion is more economic, industrial design, management, environmental/SDG, work context change or living environment/transition focused, or the need to adapt to different client terminology habits.

Is natural or technical language more appropriate in design process? People (or 'folks' in some (US) cases) is what might be used in natural conversation. But the word ‘user’ was commented as being more specifically related to design process. Changing language between design team moments and moments with interviewees was also mentioned for this reason “*utilisateur serait un peu technique*” (user would be a bit technical) for use in user interviews. In UX and user research podcasts [4] the word “people” is much more used than “user” to refer to recipients of design research. Equally the instances where “user” is used are also often in relation to an activity such as “user-research” and “user-interviews”, perhaps illustrating that “user” doesn’t work in natural language. The notion of “corporate” language was commented on by a number of participants, but perhaps “technical” language is also an issue? In an activity which progressively incorporates non-designers in all phases of projects, is there still a place for “technical” language, and for activity terminology that may be too generic and perhaps inaccurate?

There is evidence of ambiguity and diverging perceptions around people terminology. A number of terms are not as widely understood and standardised as we might assume within the design community. Participants pointed out that ‘user’ can “create qui pro quos, salespeople don’t see users as clients.” Certain terms give misleading emphasis (see the variety of meanings implied by translations/synonyms of ‘Stakeholder’ below). The terms persona, citizen, beneficiary and customer all generated diverging perceptions. The case of ‘customer’ is interesting as an example of a term linked to a design tool (customer journey map, or CJM) where the actual meaning of customer is probably closer to “user”. The term continues to be used despite the tendency to abandon words perceived as linked to commerce/consumption. A Japanese participant suggested that for ‘customer’ the *katakana* (i.e.. English) version is used, despite numerous words for customer existing in Japanese. French participants commented that ‘target’ (in English) will not have the same stigma as the French *cible*, though the meanings are the same, so both may be used with different emphasis.

Does the terminology lack humanity? Participants mentioned the need to find words to “*recentrer vers l’humain*”, (refocus on the human) and not forget that we’re dealing with people. The fact that many terms feel dehumanising was widely commented. “People are our primary material (*matière première*)” (K_UX/ED) - “user” can sound impersonal. The criticisms around “user” words in general highlight what seems to be a shared desire for giving more humanity and empathy. At the same time, we should not lose sight of the fact that early references to “human” in design process may have been about data and controllable/analysable behaviour, and the term ‘human’ was also in some cases considered impersonal. It may be relevant today to question if the focus should be ‘human’ or life? While the notion of ‘posthuman’ is sometimes used, for now the term is polysemic - evoking both a rejection of an insufficiently diverse ‘man’ focus, of non-human life forms but also of robotics [9].

Does the terminology create a distance between ‘us’ and ‘them’? Kerr et al. write that the concept of the user is problematic, with users playing a variety of roles to the extent that it can be difficult to distinguish between designers and users in ICT development [24]. Most designers seem to like the idea of terms expressing involvement of non-designers, but don’t yet feel this is the norm in their activity, particularly outside of the education and research communities. The listing exercise didn’t specifically ask about terms in relation to collaboration/co-design, but these words (participant, co-designer, co-creator, maker, contributor, collaborator) were generally very positively commented. Beyond the notion of co-design, the desire to give value to non-designer participants appears to be important - with emerging expressions such as *Wissensträger* (knowledge holder?), *expert en usage*, complex problem solver, power user/expert. At the same time, it may be important to give value without suggesting ‘expert’ users, as this might encourage working with only small numbers of ‘lead’ users, rather than generating real co-design[1].Without expressing the notion of expert, the term adopter was seen as positive; giving/respecting the agency of the person involved. How to give value, to give credit to the importance, and to avoid an implied power/knowledge imbalance?

The fact that many people considered and researched during design projects are not current users, may become users or were past users suggests variations around the word “user” are increasingly insufficient. Terminology may need to better express those beyond the user; non-user stakeholders, non-users and prospects. Equally it is interesting to note that while discussions with participants highlighted the fact that projects take into account the needs of and impact on non-users, words for these secondary actors and implicated people were not proposed by participants. Is design terminology currently lacking widely understood terms for those beyond the immediately concerned? The term stakeholder seems unsatisfactory (seen as *too corporate* by two participants), or simply strange (in all cases the participants who reacted to the expression are English speakers). “Stakeholder” perhaps lacks the sensitivity of “*partie prennante*” (those taking part?), or the notion of *communauté par intérêt* (community with shared interests) [2] The Japanese term for stakeholder would also appear to share this quality of “people with interest” or “people related by common interest”.

Beyond those directly concerned, and beyond non-human “stakeholders” there seems to be even more of a gap in terminology, but this also appears to be an area generating discussion [9],[18],[21], which may bring answers and new and appropriate language. This theme was not specifically explored in participant exchanges.

6 FURTHER RESEARCH & CONCLUSIONS

The points discussed in the previous section will be used to structure future research with a wider selection of design practitioners, through both in-depth interviews and group discussions as mentioned in section 3.2. This research generated a very positive reaction, suggesting a subject that people within the design community may be keen to see evolve. There seems to be an appetite for more respectful, more empathic ways of naming and addressing the wider range of people now involved in design activity. The names used for different design professionals are currently evolving, reflecting a changing design landscape and evolving roles. In this context is seems reasonable to question the names used for the non-designers and recipients involved in this landscape, as the roles and importance of these people increase. This preliminary research highlights that there may be dissatisfaction with parts of the current terminology, particularly for giving sufficient respect to the value, specificities and humanity of non-designer participants in, and recipients of, design process.

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THE USE OF CODESIGN BY RESEARCHERS IN PAKISTAN TO CREATE BETTER STAKEHOLDER ENGAGEMENT AND PATHWAYS TO IMPACT

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ABSTRACT

Developing countries, such as Pakistan are at the forefront of working on UN Sustainable Development Goals (UN SDGs). The problems faced by resource-constrained people (RCP) living in these countries are multidimensional [1]. Design, with its central idea of changing an undesired situation into a desired one [2] can provide holistic approaches and solutions that satisfy needs of resource-constrained people in developing countries [3]. The creation of research led, impactful solutions require an efficient and well-integrated research infrastructure and research/design capacity to design and execute research in challenging environments.

The British Council support the delivery of training courses to build national research capacity in Pakistan. Drawing on the authors' experiences of delivering such courses, this paper considers problems related to the use of codesign in impact and stakeholder engagement, project planning, and conducting fieldwork. Analysis of coursework and the 'end-of-course' world café reveals the researchers' commitment to addressing UN SDGs, lower than expected levels of participatory engagement, the challenges of working with stakeholders and tensions in research assessment methods. The paper closes with recommendations for Pakistan and ways in which this analysis and reflection can inform the design of future courses.

Keywords: Design, research capacity building

1 INTRODUCTION

1.1 Context

The development and adoption of United Nations Sustainable Development Goals continues to shape research activities in developed and developing countries. These are wicked, integrated problems [4], the true complexity of which is hard for researchers to fully comprehend when they come from HEIs (Higher Education Institutes) with more integrated research cultures operating in socio economic cultures which value research and diversity. This produces a tension in relation to knowledge transfer activities that are modelled on western approaches. Coventry University's Capacity Building Programme for Pakistan provides their senior researchers with the skills to become 'authentic scientists' [5] and the building blocks needed to create a stronger research infrastructure. This will allow the Pakistan research community to evolve, not necessarily replicate Western systems and develop context specific research approaches to addressing UN SDGs.

There is a long tradition of the application of design to support resource-constrained individuals and communities [e.g., 3,6, 7 and 8]. The underlying philosophy is that appropriately designed solutions, designerly thinking and methods can create a significant impact, supporting social and human development. Underpinning this is the belief that everyone can contribute to 'design', working collaboratively in multi-disciplinary teams driven by a shared vision to create solutions to improve the quality of life of those suffering from multiple levels of disadvantage. Implied in this is the need for meaningful involvement with end users through co-design, participatory engagement and co-creation.

Pakistan began working on SDGs in 2013, when the United Nations selected it as one of the countries to conduct consultations on the post-2015 development agenda. The key development priorities included peace and security, governance, inclusive economic growth, the rule of law, social development, gender equality and women's empowerment, sustainable low-cost energy, disaster response and preparedness, and the much-needed broader role of the developed world.

[10] recognises that addressing these problems needs partnerships across institutions and sectors to develop plans that can simultaneously help alleviate poverty, improve social inclusivity, eliminate hunger and improve health status whilst managing climate change. The Local Government Summit in 2017 raised awareness among grassroots level public officials and parliamentarians, to prioritize the SDGs in legislative business in response to local needs. Civil society and academia are supportive of the government in terms of achieving these targets. However, many challenges need to be addressed within the academic and research community such as such as financing to address local and national issues, developing a Responsible Business Framework, engaging local universities in devising local solutions for local problems, engagement of local stakeholders, training and the recognition of 'outreach and impact in career progression. This paper considers the extent to which codesign is currently employed in addressing these challenges.

1.2 Summary of the research culture in Pakistan

This section briefly summarizes the research context in Pakistan, and an explanation of why Coventry University developed a Capacity Development Programme – from which the data in this paper is drawn, Research in Pakistan is rapidly expanding. For example, the number of Pakistani PhD graduates increased by 248 percent between 1947 and 2014 [11]. In 2020/21 there were 239 accredited universities (143 in the public sector and 96 in the private sector) educating approximately 2.27 million students, with 57,000 faculty out of which 20,000 have PhD degrees, and 20,000 PhD students. However, the Economic Survey of Pakistan 2021-22 pointed out that only 1.77 per cent of GDP was spent on the education sector.

The rapid growth and underinvestment in basic research infrastructure is being addressed by the Higher Education Commission (HEC). Critical reviews [11-14] have revealed lack of adequate support for new staff, career progression and professional development, High workloads have been linked to academic burnout and issues with staff retention. Academic progression is based on the number of research publications which has led to a 4-fold increase in the number of research publications between 2006 and 2015. The Knowledge Platform report [11] documents the resultant poor quality, such as ghost writing, plagiarism, requirements to include non-contributing senior academics on papers, quantity over quality, prioritizing research which is attractive to western audiences The report stressed the need to

1. provide a greater role for academics in guiding the research agenda and funding allocation process through the establishment of research councils and the formulation of a research excellence framework.
2. allocate greater funding to Pakistan's most urgent challenges.
3. increase the appetite for university research among government agencies, the private sector, and the donor community by developing linkages and good practices.
4. cultivate communities of practice and knowledge networks.
5. drive research excellence by promoting mentoring and collaboration.
6. improve incentives to deliver impact-oriented research by revising the research evaluation system beyond publication metrics.

In response to the recommendations of the HEC, the British Council invited organizations from outside Pakistan to deliver training to improve research capacity. Coventry University's Capacity Building Programme was developed in response to the need to support researchers, at all stages in their career. The course was based on our experience of doing research in the west. Elements of the conduct and management of research are transferable (e.g., communication of research outputs, project management and the research craft per se including issues of ethics, honesty, positionality, reliability, replicability). However, as has been noted above, the reality of conducting research in Pakistan is very different. An example here is the notion of 'impact'. In the UK, and many other countries, impact assessment includes the impact of work outside of academia. For senior and STEM academics in Pakistan, impact is measured by the number of publications in high impact journals. This has skewed what is researched, how it is researched, the allocation of time developing research cultures and junior researchers and the need to use multidisciplinary approaches to design, deliver and measure social, cultural, environmental, and economic impact. This is clearly at odds with the need to address UN SDGs. Our training offered participants different insights into research practice which they could apply in their own universities. Of especial interest for this paper was the extent to which our mainly STEM participants approached impact and stakeholder engagement and considered designerly approaches to this.

1.3 Overview of Research Capacity Building Programme

Coventry University's RCBP delivered training to over 1000 researchers and research service professionals to help them to become the next generation of internationally competitive grant winners, research executives, research managers, and trainers who could develop successful bids, cascade best practice and develop impactful research contributing to Pakistan's development needs. Therefore, the overall aims of the programme were to:

- Grow researcher capacity and enable them to achieve high success rate in winning large scale national and international research grants,
- Grow a population of grant reviewers that understand and can promote and apply international best practice in grant review,
- Train and support the Principal Investigators (PIs) & Co-PIs,
- Benchmark the HEC research grant review process against international standards.

1.4 Research question

Some sessions of the RCBP focussed on writing research grant applications. Typically, these include important, and sometimes poorly completed, sections on stakeholder engagement, pathways to impact, and impact measurement. If the intended research addresses a UN SDG more consideration needs to be placed on these and a well-articulated case developed to engage with end users. The RCBP provided an opportunity to gain insight into the ways in which these, and the use of codesign or wider activities were considered.

2 DATA COLLECTION

Material for this paper was generated during the delivery of two courses for Principal Investigators (PI) and researchers (RT) in Islamabad in 2022. Participant details were collected prior to the course, with a non-completion rate of approx. 20%. Details included:

- Number attending 3 PI courses - 130, with 51 attending the RT.
- Average age 41.1 years for the PI course and 39.4 years for RT.
- Ratio of male to female, 91:39 for the PI course and 36:15 for the RT
- Number of Higher Educational Institutes represented - 55 for the PI courses, 15 for RT.
- Most participants had a Science, Technology, Engineering and Mathematics background.
- Levels of seniority ranged from Director of ORICS and research, through to lecturers. Most participants were either at the level of associate or assistant professor,

A full record of classroom activities was collected and collated during each course. The course included lectures and interactive activities on project management skills (such as diversity, creating fairer workplace cultures), presentation and communication skills, ORICS, the VITAE framework, commercialization, impact and stakeholder engagement. These themes were picked up in world café sessions on the final day of the course. Coventry University Ethics Committee provided ethical approval to use qualitative data to inform guidelines and best practices.

The data used in this paper was derived primarily from one representative PI cohort of 50 participants. Individual, 'nonmandatory' coursework associated with the lectures included participants developing pathways to impact and stakeholder engagement plans for their own research using standard templates that required the following elements:

- Stakeholder mapping - name of stakeholder group, what is important to the stakeholder, how named stakeholder groups could contribute to, or block the project, the potential strength of their impact and influence on the project and engagement strategies.
- Impact planning coursework - impact goal, stakeholders, their reasons for interest in the project, activities to engage each group, indicators to measure successful engagement, risks to activities and mitigation strategies, who would be responsible for this, resources and timing of events.

The aim of the course work was to show participants the factors to consider in stakeholder engagement and impact planning and provide them with an easy-to-use template for capturing this information.

Individual plans were shared across participants and feedback given at group level through googledocs.

The response rate indicates an appetite for research skills development in this community (with similar buy in rates found for all coursework). It should be noted the course work was undertaken after a day of lectures, with participants also having to find time to manage their ongoing workloads and commitments, and that female participants had to manage their household duties. A limitation of the study is the small data set and that time constraints might have led them to prioritize primary stakeholders and neglect community engagement.
41 sheets were submitted with 5 rejected as not including sufficient detail for the analysis. Given the focus of this paper on UN SDGs and user engagement an additional 12 were rejected because they did not have direct engagement with people (e.g., structural engineering, health data sets, drug development, animal husbandry and automotive technology) or had interpreted stakeholder engagement and impact as staff/student engagement. Of the remaining projects 10 related to agriculture, 7 to health with the rest shared between law enforcement/policing, environment, heritage (religious and cultural tourism), child poverty and education.

3 RESULTS

The analysis of engagement activities included the purpose of the engagement [15], depth and width of the engagement [16 and 17] and perceived barriers.

3.1 Willingness to address UN SDGs in a holistic manner

Across all cohorts, discussion with participants and their research ambitions revealed a deep commitment to conducting research which addressed local and national UN SDGs, such as food security, better health care, improvements in agricultural and educational processes, and dealing with problems which push the boundaries (such as religious and gender intolerance). Female participants showed a greater insight into the potential of qualitative and participatory methods. Stakeholder engagement usually included more than one quadruple helix agent, reflecting the need to involve government agencies and industry in the development of solutions.

3.2 Levels of user engagement

It was hoped to apply [16] and [17]'s criteria to the breadth of user engagement especially in relation to the involvement of resource constrained people in the development of solutions to UN SDGs. From the information provided it seemed that most activities fell well short of standard definitions of co-creation, co-design or participatory engagement. Most engagement activities related to informing and consulting. [15]'s framework deals with the depth dimension of co-design with RCPs. Although it was established that co-design was rarely present, the use of these criteria enabled an analysis of the focus of engagement activities in terms of whether it was:

1) Business driven or legitimation (i.e., gaining access to social networks and for building legitimacy of solutions);
2) Efficiency seeking – aiming to develop solutions through collaboration local partners;
3) Sustainability seeking - aiming to ensure environmental or social value; or
4) Empowerment seeking – aimed at empowering resource constrained individuals and communities.

Given the nature of the UN SDGs it was not surprising that 7 projects considered all 4 categories, Business driven engagement was most common with only 2 projects emphasizing empowerment (relating to community support for sustainable tourism and development of strategies to deal with 'out of school children'). These were also the ones that had a larger participatory engagement element,

3.3 Perceived barriers to proposed engagement

[1] provides an extensive list of barriers to codesign and co-creation activities with RCPs. Given the recognised importance of and challenges to 'end user' engagement, in developing RCBPs for developing countries, we are interested in understanding where barriers might occur so that we can co-create activities to help participants address these challenges Using a grounded approach, 3 key areas were identified which blocked stakeholder engagement. Of these end user issues accounted for most for the problems regardless of engagement type.

Table 1. Perceived barriers to stakeholder engagement

Process issues	End user issues	External factors
Need for multiple signs offs for each user group	Key players too busy to give the time to commit	Organisational/staff churn and death;
Poor research ethics – lack of responsibility, accountability, ownership and management, corruption, carelessness	CEOs and key staff do not attend key meetings due to time constraints – this signals a lack of interest/perceived importance in the project by senior people	Refusal of line manager to give time to staff to work with the project;
Inability to get necessary approvals	Lack of buy in of key stakeholder groups e.g., end users, professionals (e.g., doctors, teachers), industry sectors, target communities (e.g., Buddhists, farmers)	Overall disinterest in leading stakeholders in the need to address the problem e.g., government, local authority, key industry player and influencers
Resources (e.g., space and funding) are delayed, do not occur at the level expected,	Lack of interest in the project by RCPs, end users, industry, local authorities, government, informal sector, and communities	Lack of understanding about the need for the research/importance of the issue
Poor communication and product marketing	Lack of access to key participants due to gatekeeper controls (e.g., children, patients, women)	Political instability
Inappropriate sampling and methods		

4 SUMMARY AND RECOMMENDATIONS

The RCBP showed a clear need to increase basic research skills and improve the research culture. Our cohorts included national and internationally renowned subject experts. However, many had not received any form of research capacity development and were not familiar with the wider responsibilities of research leadership (such as mentoring, creating a research culture).

- Recommendation 1: Codesign a RCBP focusing on research centre development rather than individual skills which recognizes the current research infrastructure and culture.

Participants were committed to research which addressed national issues.

- Recommendation 2: Prioritize funding to address UN SDGs as they are manifest in Pakistan.

Participants were very aware of the problems associated with such engagement, many of which are context specific. However, in the RCBP we focused attention on academics, rather than fieldworkers and NGO staff who have greater insights into participatory engagement.

- Recommendation 3: Map out existing pathways to impact and stakeholder engagement plans that have had a demonstrable effect, with a view to creating research practitioner resources that can be incorporated into grant applications.
- Recommendation 4: Create high quality opportunities at local, regional and national level to share insights for all stakeholders, and users to share insights g. conferences, round table.
- Recommendation 4: Reward and disseminate excellence in innovative ways to engage with quadruple helix agents.

With a rapidly expanding research community, a pressing need to address UN SDGs at a national level and constraints on research funding, there is an urgent need to ensure high quality grant applications which produce real world impact.

- Recommendation 5: Provide reviewer and participant training for grant applications. Incentivize the delivery of constructive feedback on these sections of grant application. Ensure that resources can be included to cover costs of meaningful engagement and impact assessment.

Our cohorts were mainly drawn from STEM disciplines. As such they had only limited understanding of other disciplinary approaches and how these might assist in creating more meaningful stakeholder engagement and pathways to impact. Of special interest in this paper was the lack of awareness of co and participatory design approaches, living labs etc.

- Recommendation 6: Create and share greater awareness of how designerly approaches are being used to address UN SDGs in Pakistan

Design is recognised as a crucial in addressing UN SDGs. Researchers attending our RCBP were predominantly from a STEM background. Widening their understanding and recognition of designerly ways of thinking and approaches, may help deliver against UN SDGs in a more holistic manner and increase stakeholder engagement and impact.

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WHAT DO WE CREATE IN A RESPONSIBLE WORKSHOP IN 2030?

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ABSTRACT
What should design students learn, not to lose hope, but be able to design in the current dire climate, energy and health situation? What can we design and still stay on track with the Sustainable Development Goals (SDG) in 2030? What can we design in the long run, not worsening critical human and non-human systems? In the paper we question "good intentions" and business-as-usual approaches, to challenges facing many of our most existential systems. We suggest changes to the Design field's understanding of the SDG's. Further, we suggest focusing on several solutions at the same time, in local communities, with collaboration with others and design educations. The paper argues that a holistic and systemic view is required that rather focuses on root-problems, than the symptoms these problems cause. Based on a multidisciplinary selection of scientific literature, the paper shows how acclaimed systemic approaches often harm the health of both human and non-human systems. In addition, the paper argues that these acclaimed systemic approaches tend to suggest "solutions" that stand in the way of more realistic solutions emerging from supportive and social environments. One of the insights from the literature, is how individuals by reconnecting to community- and practice-based activities strengthen hope of better futures. In the paper we argue how designers and design educations, can act multidisciplinary, with others, to become agents towards the kind of holistically, community-based, and radical changes required to heal all broken systems. We suggest how designers can situate themselves in the responsible workshop of 2030.

Keywords: Design workshop, health promotion, SDG, systemic thinking, local community

1 INTRODUCTION

1.1 Current sustainability goals for economic growth
This decade is considered the last we have to get our act together and heal what a small part of humanity has broken during, especially, the last half-century [1]. To stay on the track established by the "Paris Agreement" [2], we know that global emissions must be halved by 2030 and reach net zero by 2050 to avoid climate catastrophe. However, this decade is also the last for its year mate, the 17 Sustainable Development Goals – the SDGs – that was launched 2015 [3], to be achieved according to its own schedule. Despite that, the first challenge – climate change – is arguably an existential deadline, and the latter – the SDGs – tends to be more of a set of goals to stretch for; they are not only intimately interconnected, but they also share many features, approaches, mindsets, failures, and critiques. For this paper, we will content ourselves by initially, as a mere backdrop, point out that neither the current climate policies nor the SDGs question the current system's fundaments, e.g., clearly illustrated in the criticised SDG8. Both sets of goals seem, so far, to fail [4, 5]. Or in other, more specific words, they both state specific metrics to be met to achieve their goals but arguably avoid questioning the systemic roots of the problems it tries to solve. One way of understanding this consistent but puzzling pattern is to learn from the late system thinker Stafford Beer *"The purpose of a system is what it does. This is a basic dictum. It stands for a bald fact, which makes a better starting point in seeking understanding than the familiar attributions of good intentions, prejudices about expectations, moral judgments, or sheer ignorance of circumstances."* [6].

1.2 Sense making through system thinking

The significance of Beer's insight becomes evident if one applies it to findings one can find in a recent Oxfam report [7] that claims that the *"10 richest men in the world own more than the bottom 3.1 billion people"* and that the *"twenty of the richest billionaires [each] are estimated, on average, to be emitting as much as 8000 times more carbon than the billion poorest people [do together]"*. The relation between development and climate breakdown and the fact that a few that live far beyond the means, force many more to live far below what ethically would be their fair share of available resources, is further underpinned by Figure 1 [8].

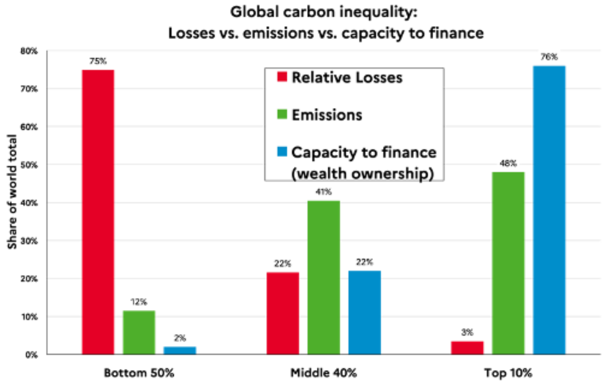

Figure 1. From the climate inequality report 2023 [8]

The brief introduction above is meant to introduce established Systems Theory as a tool for sense-making. In section 2 we illuminate broken and intricate system connections between humans and non-humans. Based on these explorations focusing on Health in section 2, we discuss in section 3 how this relates to Design and its education. Finally, in section 4 we end with a discussion about the kinds of radical changes we believe are required to make a difference that makes a difference [9].

2 HEALTH & THE BROKEN CONNECTION – HUMANS AND NON-HUMANS

Health is arguably a human right and number 3 of the 17 Sustainability Development Goals [3]. Health is defined in diverse traditions [10]. Mainstream *biomedical* health that you get from your local MD, large hospitals and drugstores, focuses on medical treatment of *symptoms* of illness, or *Pathogenesis*. See 2nd column on Biomedical Health (table 1.). It is run by pharmaceutical companies, mainly driven by demands of economic growth. Digital health services, welfare and assistive technologies, sensing and monitoring elderly persons when falling at home and automating the care, are thought to solve the demographic challenges with more elderly persons and fewer health personnel. A critique of biomedical health is that it is breaking many of the since long developed networks of relations, *assemblage* [27], by prioritizing only relations that increase revenue for the shareholders, whether it is the relatively simple monitoring of blood levels with new wearable sensors, or administering off-the-shelf cholesterol lowering medicine for people that eat junk food rich of fat and sugar. Under this reasoning we like to point out two different nested models of thinking, described in table 1: The first model is "Growth, Ecology part of Economy" (column 1), based on growth, where *Economy* always is prioritized over ecology. The second model is "Holistic, humans and Economy part of Nature", (column 3), based on holism, where *Ecology* is prioritized and economy, technology, design and humans are subordinated. We argue for the importance that designers recognise these different nested models of thinking. Otherwise, the risk is that we are solving the wrong problem. The current administration of medication against cholesterol might be more inclined to merely keep you alive than having any real incitements to heal you completely. Similarly, it is possible to generate revenue from designing symbolic greenwashing products with *good intentions* rather than solving the root-problem defined in the SDG [3]. A counter reaction in health care systems focuses on that every human has Positive, or *Salutogenic resources* [11] (see 4th column in table 1.). Even if a person does not see very well, he or she can still communicate by talking and touching. Resource-orientation is being used in elderly care and rehabilitation, together with strategies such as person-centric health care and public health in whole societies and the local community.

Table 1. From Economy-Driven Growth models for SDG, nature and health, to Holistic models for nature and health: radical changes in design disciplines and design educations

From: *Economy-Driven Growth models for SDG, Nature and Health*		**To:** *Holistic models for Nature and Health*	
<u>Sustainability (SDG 2030)</u>	**<u>Biomedical Health</u>**	**<u>Non-human Health, Nature</u>**	**<u>Human Health</u>**
Growth, Ecology part of Economy	Medical industry, increase revenue	Holistic, humans and Economy part of Nature	Health Promoting (WHO)
Business-as-usual, Global economy	Pathogenic/ illness	Community driven, Local economy	Salutogenic/resources of wellbeing
Climate above 1.5-2 degrees	Hostile environment, bacteria,fungus,virus	CO2 neutral cyclic local energy, food production	Supportive Environments (WHO), assemblage of humans/nature
"Good intentions"	Symptoms treatment	Real existential	Preventive, social relations

2.1 Health promoting supportive environments

Health Promotion [11] was defined by the World Health Organization's in 1986. It is a holistic definition of health, strengthening community actions and with the goal to engage persons in policy making, design and experience of health and wellbeing. To be Health Promoting, we argue, a service, product and activity needs to create networks, or *assemblage* [27] between humans and things/non-humans/nature in what is called *Supportive Environments* [11] (see 4th column in table 1.). In the environment, ecological, physical, psychic, social and aesthetic aspects are influencing a person's or a society's health. These can all be positive, or *Salutogenic* health resources for a person that is in treatment. Examples of Health Promoting activities prescribed by local medical doctors are hiking in nature, Garden Therapy for persons with burn-out-syndrome, and everyday Music and Health sessions. Music played or sung during the day in elderly care centres [12], is helping elderly with severe dementia to uphold their identity and to remember their past through the music that they know and have a relation to. Norwegian initiative such as the "NaKuHel" (Nature, Culture and Health) [13] is an organisation with a farm with evening courses, conferences, social and leisure programmes with a café for local citizens, elderly persons and children in outdoor kindergarten and hiking tracks outside of Oslo. NaKuHel is a Supportive Environment [11], run based on Health Promotion and with public health goals of strengthening the local community and the society.

2.2 Non-human health

Based on a holistic worldview, we like to see similarities and create relations between health and the environment. None-human health can be viewed as a holistic ecological system.

Regardless of one's own stance it helps, as suggested by the famous scientist James Lovelock, to think of nature's all sub-ecologies as parts of a giant global self-regulating system or even as an organism in its own right; an organism Lovelock coined the Gaia [14]. The scientific warnings for just a few degrees increase in average temperature, then make so much more sense. *Gaia is then about to run a serious fever* [15] leading to unpredictable conditions caused by the gigantic increase of energy running our climate systems and by that threaten many of its important subsystems [16]. The health situation is already very serious at some parts of its body and if no remedy is found the disease will most certainly seriously affect its whole body and eventually lead to global ecological collapses. Collapses, or "*tipping points*", where we reach a trajectory of no return and whatever we then do will be in vain. In a narrative like this, a small part of humanity has turned into a malevolent bacterium that does not seem to understand that its selfish parasitic actions endanger everyone's existence, including their own.

Despite that the leading scientific authority, IPCC, whose consensus-based legacy is to lean toward the more conservative side [4], the fifth IPCC assessment in 2021 issued a blunt message; *"Due to the carbon already released by human activities, it warned, major climate changes are inevitable and irreversible on the scale of human lifetime. Furthermore, in the absence of immediate, rapid, and large scale reductions in emissions, limiting the global average temperature rise, since [preindustrial] time, to 1,5°C or even 2°C would be impossible"* [Ibid p.13].
This arguably render the simple question; **should we believe in science or not?** The stance of this paper is that we should trust what science tells us [17], acknowledging the immense consensus about the causes [18], and based on that information making us more immune to the influential and ubiquitously present disinformation we all are affected by and telling us to do the opposite [19], [20]. But perhaps most important, act accordingly!
To conclude this section, we argue that that Gaia's health is, to paraphrase the first sentence in David Wallace-Wells' seminal book The Uninhabitable Earth: life after warming: *"it is worse, much worse, than [we] think"* [21] and therefore requires urgent actions that's far more radical than the kind of remedies employed today. Remedies, we argue, only try to address symptoms without touching the cause, an approach that so far, unsurprisingly, proven completely insufficient. In fact, it has been far more talk and "good intentions", than serious action with real positive changes (compare 1st and 3rd column in table 1.). Or as Bill McGuire [4:10], so to the point, phrase it: *"To say that the formulation of such policies has taken place in a snail's phase would – in all honesty – be insulting to molluscs"*. We need to seriously ask ourselves: Why?

2.3 Healing as reconnecting to hope

We argue that an aspect of understanding Health and Health Promotion, between Humans and Non-Humans/nature, is to understand the transition of *healing*, in the meaning of getting "*whole*". It is the same word as in *holistic*, meaning to see the sum of the whole, rather than the individual parts, the network or assemblage of possible relations. Johann Hari describes how poor (mental) health is a process of losing connection to oneself, other people, work, nature, and how healing that, is to design strategies to reconnect it all again [22].

3 DESIGN AND DESIGN EDUCATION

Designer Enzio Manzini founder of Social Design Labs all over the world (DESIS Lab) and professor at ELISAVA School of Design and Engineering in Barcelona, makes the statement: *"design capability is human capability"*. He defines what we consider to be "design's DNA", as the combination of three very human gifts: 1) to be critical of the state of things around us; 2) to be creative, imagining something different from the present state of things; 3) to use our practical sense to understand if what we have imagined is viable or not. [23].
We see that many design students have *lost hope for the future*, lost connection [22], and have given up hope that anything could be any different. Where are we? We believe that, if the next generation of designers is not *imagining* futures with climate and holistic health promoting technologies in mind; we probably are in deep trouble.

3.1 Design's current systemic role

A system's view reveals that most design disciplines are "kids of their time", typically emerging as a response to what the system needed most at that specific time. Here are some brief snapshots of the history that have to suffice [24]. With the *specialisation* during the *industrial society*, we could see how the craftsmen diverged into *workers* on the one hand and "*specifiers*" like industrial designers and engineers on the other. In the last half-century, the speed of change has accelerated, first with the so-called *information society*, with a need to increase the market potential of the, at the time, very cumbersome digital systems by making them more user-friendly. This gave birth to Human-Computer Interaction and Interaction Design. The information society was soon followed by the so-called *Service Society* and a system that needed further commodification of what until then had remained in the non-commercial private sphere, which arguably gave birth to Service Design. More recently, *System Theory* entered the sphere of design [25], being what we here try to use as a tool to understand the mess we designers (and engineers) have been so instrumental in the creation of.
The point to *take home* here is the narratives we tell, regarding *whose interests* we as designers and developers really are advocating. Compare 1st and 2nd column in table 2. It is challenging to realize

that the current economic system gets primacy whenever its "*existential needs*" do not resonate with design's "*good intentions*" (cp. Beer above) [7] and our profound belief that we are the users' advocates. Despite that, the system's existential needs then, in turn, jeopardize everyone's most existential needs.

3.2 Potential new roles for design

What should design students learn, not to lose hope, but be able to design in the current dire climate, energy and health situation? What can we design and still stay on track with the Sustainable Development Goals (SDG) to be realised by 2030? What can we design in the long run, not worsening critical human and non-human systems?

Considering these pertinent questions, what role(s) should design have in the future? What does it mean, that we should take the climate and energy challenges of the future seriously in the design concepts, user-insight and development work we do? Or should we re-educate ourselves in a more fundamental way? Should the Interaction Designer and Industrial Designer of 2023 become community workers, facilitators and co-designers of group work, coordinating different crafting capabilities to understand and hack electronics, solar cells, farming and health and sustainability? Or should we become policy makers designing political campaigns and action plans for local communities to deal with crises and lost connections [22]?

Table 2. Community Futures design workshop. From: traditional Design, form and individual user. To: radical changes through community and system thinking in design educations

From: *Traditional design, form, individual user*	**To:** *Community design and system thinking*
Designer as user's advocate, "good intentions"	**Co-Designer, multidisciplinary facilitator**
Economic growth, with "good intentions" for climate and health	System thinking, nested complex system
Attention economy, UX, next kick	Relational, Community-driven
Design as form-follow-function	Re-Futuring, Radical change
Upholding carbon-based economy	Design for diversity, value-driven

4 DISCUSSIONS

We argue that one of the most important skills to learn and practice in the future responsible workshop in 2030, is to be able to analyse the narratives and underlying multidisciplinary models. First, then, can we situate ourselves as designers and contribute with effective and sustainable solutions. In table 1. we describe the current broken system, on the left. The Sustainable Design Goals in column 1 are based on a model of economic growth. Biomedical Health in column 2, also builds on growth, but in a Pathogenic illness-focused health paradigm. Neither of them prioritise nature, nor health, but the Economy. Until now the design practices (table 2) have at best focused on being ethical "good", arguing that taking the user's perspective (1st column) is a "good" act. This is not necessarily true. More commonly, design has been, and still is, introvertly focused on form-follow-function. Again, this is based on what is economically viable. Based on this analysis, what changes should we prioritise (see 2nd column of table 2), and how would it be possible to introduce them? Our suggestion is to move from teaching Sustainability based on economic growth to *non-human health that is holistic and based on Health Promotion and System Thinking*. One set of bottom-up methods we have argued for in the paper is to work with others, *listening* and *co-designing* in local communities. Working with local energy and food production will hopefully bring us closer to *real existential challenges*. We believe it will give us a chance to address what gives a community hope, and how the community master *real skills,* not good intentions. The more we have worked with the combination of Non-Humans and Humans, the harder it has become to separate between them and to uphold binary division between nature and humans. We found it useful to be able to work with, visualise and share more complex models that make it possible to draw and map relational networks of all actors, humans and non-humans involved. There are also intentional overlaps between models in the different fields of Design, Health and Sustainability that showed to be fruitful and should be explored more closer in practical workshops. Health Promotion have coined the term Supportive Environments [11], which overlap with physical environments in ecological and social sustainability. It does also overlap with co-design processes of idea creation and Re-Futuring [26] in the design field. Common for all three fields are abilities to listen, communicate, situate oneself around emotions, technologies, theories, visualisations, imagination, and hope for the future.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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DESIGNING AN ECOFEMINIST UTOPIA

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ABSTRACT
This article proposes an educational module that promotes the study of ecofeminism within product design in high education for ethical design thinking. Design materialises concepts and leads therefore to realities; accordingly, it is important to provide a design education that acknowledges the significant changes design could make when loaded with ethical values. Ecofeminism is a philosophical current that involves the intersectionality of feminism and ecology, concepts that encompass gender and sustainability. Ecofeminist politics work with a focus on women and non-human nature, with the aim of liberation from power interactions and marginalisation inside society structures, gender equality, and ecology. Consequently, an ecofeminist design perspective is committed to having a care-centric vision towards gender and environmental protection. This proposal presents a collaborative methodology using utopian theory as a creative strategy for learning. Utopia is the idealistic illusion of a perfect reality, thus, utopia as a vision can be the trigger to reflect on the paths our society should follow for further development. Furthermore, feminist utopia focuses on building the bridge between reality and illusion, thus, utopia is a precise cognitive act that could be a beneficial tool for design creation. Unifying ecofeminist philosophy and feminist utopian thinking, this paper presents an innovative way of working with ethical considerations in product design. Hence, it aims to improve the awareness of the need for a sustainable society in future designers, engaging them with some of the UN Sustainable Development Goals such as 5. Gender equality and 12. Ensure sustainable consumption and production patterns.

Keywords: Product design, feminism, ecofeminism, utopia, higher education, ethic values

1 INTRODUCTION
Taking into account the strength of design in society, ethics and morality should be incorporated into the education of future designers. Although educational environments usually provide moral learning in transversal competencies, it is nonetheless important to emphasise the reflection of ethical thinking in product design education to promote the consciousness of designers. In this proposal, I focus on two of the most important areas that currently require ethics in design thinking, ecology, and gender equality, both of them covered by the UN Sustainable Development Goals.
In the present day, there has been a shift toward sustainable strategies promoted by ecological thinking in product design; For instance, the engagement with the purpose of societal degrowth [1] has been embraced by various activists and academics, however, ‘growth as a paradigm needs to be sustained because it is the unquestioned basis for social security, labour markets, policymaking, citizenship, and corporate activities [2]. Therefore, design is not only challenged by the product's demand but also by the concerns and struggles of its socio-political context [3].
At the same time that product design establishes relationships between humans and the Earth as a production source, it can also determine human interactions. Traditionally, design has defined gender roles, stereotypes, and inequalities by making gender-specific products [4], yet we can always escape to utopia, away from the symbolic and oppressive role patriarchal society has set for us.
In response to this matter, this paper reflects on ecofeminism and how to use utopia as a methodology for socio-structural changes, thereby giving a possible answer to Cecilia Åsberg's wonders of ‘what kinds of ethics and critiques, arts and sciences, politics and methods, can account for the changes in spatial and temporal scales introduced by climate change, species extinction, the life sciences, or the emergence of the politics of Life itself ’ [5].

2 THEORETICAL BACKGROUNDS

2.1 Product Design and Feminism

The Frankfurt kitchen, designed in 1926 by the Austrian architect Margarete Schütte-Lihotzky, was an innovative design that proposed an efficient method for domestic tasks. In the context of the 1920s, women were trapped in the domestic sphere, thus to the kitchen, which is why Schütte-Lihotzky designed this kitchen from her feminist perspective. If women could do domestic tasks faster using this design, they would have more free time for themselves. However, although Schütte-Lihotzky's idea was to liberate women from domestic labour so that they might explore cultural or intellectual activities, in the 1970s and 1980s, feminist critics condemned her design for not being a feminist [6].

Feminism is a constantly evolving movement in favour of gender equality, thus, its needs change according to time, and this evolution also impacts product design. For example, if we look at menstruation products, they have been developed for the comfort of the user, at first the design of the napkin and later the tampon, later on, products such as the menstrual cup [7], and even panties with new highly absorbent textiles have been developed, both of the last engaging an ecofeminist vision due to their reusability capacity.

On the other hand, there are product designs that support the feminist movement. For instance, the tool that aids in women's sexual liberation [8], or designs that consider the female body anatomy. Moreover, some products have been developed to help protect women such as anti-rape products like FemDefence or Invi Bracelet, and mobile applications like Legal Fling [9].

However, many products still promote gender sexism or anti-feminism; A case study is the Pinky Gloves [10], created in 2021 by a group of German men, these pink gloves are designed so women can change their tampons or pads without touching menstruation. Instead of appealing to feminist needs, the product acts against feminism by promoting the stigmatisation of menstruation

Feminism and the realities it postulates require new products that support a new structure, and because of this, it is necessary to rethink product design. Additionally, when designing a feminist product, we not only have to think about whether the product fulfils the final goal or not, but also to reflect on how it achieved the goal.

2.2 Ecofeminism: A design perspective

Ecofeminism is the philosophical current that unites feminist ideology and ecology in a commitment to a sustainable and ethical society. In the words of the academic writer Karen Warren [11] ‘Nature is a feminist issue, which might be the slogan of ecofeminism’. The term ecofeminism appears for the first time in the work Le Féminisme ou la Mort (1974), by the writer Françoise Dieudonne, defining an ideology that establishes a connection between women and nature. This term is born from and in favour of the fight for the liberation of nature and of women, who have been devalued and exploited.

The first conceptualisation of ecofeminism was in the 20th century, a biological determinist relationship in which women are connected to nature by their ability to menstruate, give birth and breastfeeding was made. These early ideas are referred to as classical or essentialist ecofeminism, but their content has been evolving and acquiring new forms through different writers and authors such as Yayo Herrero (2016). She defends constructivist ecofeminism, which emphasises the historical marginalisation that both women and nature have suffered in a patriarchal society as the reason for the emergence of ecofeminism [12].

Ecofeminist politics explore new ways and dynamics that avoid dominance and subordination interactions that hinder justice for women and no-human nature. Both women’s and nature’s value has been defined in relation to profit and therefore with capitalist doctrine, with the subordination of their living rights to that which benefits production.

Greta Gaard argues that women and nature could not find their freedom without the liberation of the other, hence, feminism and nature need to establish a symbiotic relationship based on their cultural, anthropological, and historical connections [13]. Consequently, this revolution could change the relationship dynamics between genders and our relationship with nature [14].

For this liberation process that addresses gender inequality and the ecological crisis, the ecofeminist Rosemary Ruether proposes a ‘radical reshaping’ [15]. On that account, incorporating ecofeminist thinking in product design could play a crucial role in this revolution; through product design, designers can materialise ideologies into objects, so, they have the power to design the pieces for a sociopolitical structure transformation.

Within ecofeminism, is proposed a care-centric-vision [16]. This position considers that the main lynchpin of all our relations should be the understanding of caring to achieve inclusive and respectful equality. It can be said that product designers have an intrinsic relationship with customers since the conceptualisation and production of the designed product will have a repercussion on the customers, consequently, a care-centric-vision should be a value we should consider in the designing process. As design materialises concepts, and we conceive and understand the world in terms of that materialisation, promoting an ecofeminist perspective in education could enrich sustainability and gender equality ideologies.

2.3 Utopianism: Feminist utopianism reflection and practice

Utopia is defined as the imaginary scenario of an ideal society; therefore, this product of an illusory reality is a cultural artefact [17] that contains the representation of the society that we are aiming to achieve. Accordingly, the information about a dreamed utopia could be used as a potential driver to lead the development of current society. The construction of a utopia, allows us to acknowledge which characteristics of society would have to change for a perfect future, hence, utopian thinking 'reflects on politics and society, which seeks the perfect, best, or happiest form of society, untrammelled by commitments to existing institutions.' [18].

Although the term utopia is often understood as a naive way to imagine the unattainable, thinking without the limits of reality, can also be a beneficial strategy if we analyse it critically. Using utopian thinking we can diagnose societal structural ills and distinguish the problems that exist today as well as the goals we want to achieve. Hence, it is on this last idea that feminist utopianism is focused.

Feminist utopianism is 'situated, critical, and relevant to transformative politics, a view structured by embodiment'[19]. Instead of understanding utopism as a mere fantasy, feminism uses it as a tool for progressive thinking. Through utopia, we can conceptualise new structures and explore new gender dynamics toward equality. Furthermore, 'to deprive feminism of its utopias is to depoliticize it at a stroke' [20], as feminism fights for gender equality and against hierarchies of inequality. Thus, its hope rests in the belief in achieving that utopia. In the words of the feminist philosopher Seyla Benhabib, utopian thinking is 'a practical-moral imperative' [21].

Because of its values for progressive thinking, writers such as Ruth Levitas have researched utopia as a method for the reconstruction of society [22] finding different perspectives to use it as a tool. In this proposal, I focus on the two main concepts that synthesised the utopia theory: Utopia as a vision and utopia as a cognitive act [23]. Utopia as a vision refers to the idealistic picture in itself, the dream, and on the other side, utopia as a cognitive act is the action of utopian thinking, thus, the act of establishing connections between the illusion and reality to develop toward utopia. Feminist utopianism especially focuses on utopia as a cognitive act since it is the activist mindset that searches for a method to bring utopian thoughts closer to reality.

3 A PROPOSAL TO APPROACH ECOFEMINISM IN PRODUCT DESIGN HIGH EDUCATION: EDUCATIONAL DESIGN AND METHODOLOGY

The ideas presented below are designed for an educational proposal focused on the reflection and materialization of feminist product design or the transformation of products that do not conform to a feminist ethic. This approach is based on an ecofeminist perspective and the use of feminist utopia as a strategic tool for design.

3.1 Pedagogical Methodology

This proposal will benefit from the following methodological insights and tools; *collaboration, social constructivism, dialogical analysis and meaningful learning.*

Within the educational context, Maldonado [24] defines collaborative work as an interactive learning model in which students build knowledge together, combining skills and efforts to achieve common goals. We understand collaborative learning as a process in which all members acquire knowledge in a symbiotic relationship, giving and receiving feedback in cognitive construction. Therefore, collaboration has an inclusive perspective that takes into account the diversity of the individuals and, consequently, the plurality of their contributions to the group. This means that heterogeneous working groups could benefit the exchange of ideas and learnings being beneficial for the reflections of ecofeminism.

Through collaboration, sociocultural constructivism will shape learning, based on social interactions, interpersonal relationships, and culture [25]. For sociocultural constructivism, the use of dialectics is essential to understand a subject since interrelationships and contradictions are essential for its constitution. Accordingly, in our proposal we will build knowledge through dialogic analysis, which will be carried out collaboratively, generating a sharing network of enrichment [26]. Feminism, ecology, and ecofeminism are being redefined and transformed every day as a consequence of constant social development; collaboration is the key to exploring this ideology.
With this pedagogical stand it is proposed that the educator figure facilitates the activity instead of leading it; the educator is responsible for keeping an active and reflective environment during the sessions, hence, the students will explore the different sections of the module acquiring the learning progressively.

3.2 Designing ecofeminist products

Table 1. Example of a table

Section 1	Introduction to ecofeminism in product Design	Analytical dialogical analysis
Section 2	Utopia as a vision	Creative thinking
Section 3	Utopia as a cognitive act	Cognitive design practice
Section 4	Sharing and evaluation	Analytical dialogical analysis

3.2.1 Section 1
This section is an introduction to the topic, which is expected to use dialogic analysis to explore the topic with the participants. The theoretical data will be used as a trigger to create discussion.

3.2.2 Section 2
This section will be used to set off creative thinking. As we mentioned before, utopia as a vision refers to the idealistic society, in this activity utopia dreaming will be used as a method to find new scenarios, shapes, necessities, and consequently, new products of ecofeminism. This exercise aims to give the participants a secure space to fantasise about a new reality, and this illusory word would be materialised by drawing or constructing different sketches.

3.2.3 Section 3
Following the dream, reflection comes. After participants have framed a perfect ecofeminist alternative reality, they would use design thinking to adapt those sketches and make those dreams come true. In this section, participants will be divided into small groups to have easier coordination. As feminist utopianism does, in this exercise participants would have to use utopianism thinking for progressive strategies, building the bridge to connect utopia and reality through design.

3.2.4 Section 4
The last section aims to share the products that the participants have designed and the concepts that they have developed. It is important to use this section not only to assess the products but also to evaluate participants' interactions, thoughts, and feelings during the proposal. When this proposal comes to practice, it is important to emphasize students' desires and the possibility of them being actively involved [27], consequently, developing meaningful learning [28], learning through which the learner establishes a relation of interest that enables the non-trivial relationship between the new knowledge and the knowledge he already possesses.

3.3 Educational outcomes
This proposal aims to benefit students by providing them with the following outcomes:
- Reflection on sustainability in the interconnection of gender, economy and society from an ecofeminist perspective.
- Learning to work in collaboration for sustainability.
- Practising the outcomes of creativity as an enhancer of future designs.
- Reflecting on the impact of design on socio-economic systems and its repercussions.
- Understanding design as a tool against inequalities.

4 DISCUSSIONS

Although the concept of ecofeminism was born in 1974, its incorporation into educational spaces has not gone hand in hand with sustainability, as an example, an analysis presented in 2022 on 55 eco-social museums in Spain reveals how ecofeminism is not present in the majority of them [29]. However, in the last decade, the reception of ecofeminism in high education has been remarkable due to the qualities of its holistic perspective. A case study, conducted at the University of Valencia, Spain, shows how only three out of 188 pre-service teachers had any notion of what ecofeminism was, thus, the research proves how a module of ecofeminist reflection can positively impact attitudes towards sustainability [30]. In 2020, this same university carried out a study that presented creativity and ecofeminism hand in hand for the realization of educational stories, the students showed reflective and academic mastery, however, they lacked originality [31].

Dystopias such as Yabarí, a novel written by Lola Robles which explains the complexity and importance of ecofeminism, vividly reflect the need for eco-social changes, indeed, further from the representation of the problems we need to respond with strategies for the solutions. Therefore, this paper believes in utopia as a visualization tool, in order to follow Jules Verne's steps, who in his book Twenty Thousand Leagues Under the Sea (1870) devised the Nautilus vehicle, 18 years before its creation in 1888. Gert Selle already reflects on utopian design in the book Ideologie und Utopie im Design in 1973, a book that makes an overview of design history from social criticism and the aim of well-being [32], consecutively, for the analysis of the current systems, solar punk postulations could be the source of inspiration. Solar punk is the genre of utopia focused on eco-social sustainability, this genre is a branch of literary fiction that explores in its narratives technological futures based on sustainable scenarios [33], thus, these scenarios could be understood as the ideation of new futures.

5 CONCLUSIONS

This proposal is a pedagogical project that enhances the design thinking of the participants and enforces an activist perspective to design. The paper promotes the need for an education that explores ethics and new possibilities to change this hierarchical world. Through ecofeminism, we can analyse the power relations that subordinate women and nature, and consequently, activate our consciousness to reestablish a new social dynamics system. This practice moves forward to solve two of the UN's SDGs, 5. Gender equality and 12. Ensure sustainable consumption and production patterns.

The session Utopia as a vision was put into practice at Studentenes Feministiske Forening, the feminist student association at UiO, University of Oslo, the participants describe the workshop as stimulating and hopeful for the movement. In conclusion, this paper presents a methodology for the deep reflection of ethical thinking current product design demands. By implementing these ethical values in product design, we can materialize a sustainable vision, which engages feminism and ecology. This innovation proposal is one of the ways feminism and ecology can be introduced in higher education to promote sustainable design.

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A MODEL OF CULTURAL INCLUSION THROUGH THE INTERACTION BETWEEN ARTISANS AND PRODUCT DESIGN STUDENTS

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ABSTRACT
Although handicrafts are recognized nationally and internationally as part of the identity and popular culture of Mexico, artisans, due to their condition of economic, educational, and geographical penury, find themselves in unfavourable conditions to sell their products in attractive markets or negotiate important contracts, normally carried out in spheres inaccessible to them [1]. Artisans are forced to sell their handicrafts at very low prices in the streets of the country's tourist cities, suffering discrimination from potential customers who have the economic capacity to buy their products, allocating insufficient value to their work because usually handicrafts design does not satisfy their functional or aesthetic needs, haggling over the price.
Tecnologico de Monterrey is a private educational institution ranked number 1 in Mexico [2] which has a high social commitment and seeks to reverse these types of situations. Therefore, professors and our courses can be agents of change and promote healthy and productive relationships. This article describes a proposal to motivate inclusion and cultural co-habitation, with a teaching-learning model developed in the Design and Handicrafts course, which is part of the minor in Art, Object and Fashion of the 2017 programme of the bachelor's degree in industrial design, that was taught at Campus Querétaro in the semester of August December 2022. The course promotes that artisanstra teaching the basics of traditional techniques to future designers, to letting them know the origin and tradition that artisan work represents while appreciating the cultural heritage and manual dexterity, generating a relationship of respect and empathy, which could trigger healthy and fairer future working relationships for artisans and future designers.

Keywords: Educational innovation, higher education, cultural inclusion, cultural co-habitation, design entrepreneurship, design for value, handicrafts, social innovation, social development, design workshop

1 INTRODUCTION
Since time immemorial humanity has learned to live hand in hand with nature. Humans learned how to feed, how to heal and how to predict the weather to take care of themselves. Our ancestors discovered how to work the materials of their environment manually elaborating utensils and tools that increased their strength and facilitated their tasks. They created farming tools and developed agriculture, built boats and with the help of the stars, they ventured to conquer the seas, thus discovering every corner of the world. All, with the help of nature and the objects they designed and manufactured with the raw materials they obtained from it. Today, in our industrialized world, we call those objects handicrafts. Throughout history, every social group on the planet has felt the need to express their way of life and customs, thus inheriting all their knowledge to their descendants. The product of this expression is embodied in different ways and through different activities, such as language, writing, dance, music, painting, gastronomy and of course handicrafts, which together conform part of the essence of the culture of people.

2 TRANSITIONS FROM HANDICRAFTS TO INDUSTRIAL PRODUCTS
In 1775, at the beginning of the Industrial Revolution, and the first steam engines were to be incorporated into the production lines, artisans, who manually produced the consumer products of that time, were

able to produce more and at a lower cost thanks to machines. During these early years of transition, the shape of the first industrial products tried, clumsily, to emulate what was once made by hand. Fortunately, around 1845, the efforts of Henry Cole, and later of the Arts and Crafts Movement, led by William Morris, took it upon itself made it their objective to retake the principles of purity and honesty in the appreciation of handcrafted materials and techniques, incorporating them into the nascent mass manufacture of products [3]. Craftsmanship, which was the technological basis of industrialized production, was diluted as the volume of production increased, but its cultural and aesthetic essence has been maintained and is mostly respected to this day. There were plenty of European manufacturers of furniture and household appliances that had have their origin before the industrial revolution [4]. This was not the case in Mexico, where handicrafts and industrial production followed separate ways. Nowadays, industrial products are usually imported and sold in department stores and large commercial chains of foreign origin. Handcrafted products are marginalized to local markets or tourist's stores, of much lower volume and outside the usual points of sale for urban consumers with better economic capacity.

3 CULTURAL VALUES OF HANDICRAFTS IN MEXICO

In pre-Hispanic Mexico, the period before the Spanish colonization, that is, before 1519, handcrafted objects occupied a very important place at all levels of the social structure, satisfying all kinds of domestic, labour and spiritual needs, giving rise to the development of the diverse techniques we know today. According to Fonart (National Fund for the Promotion of Handicrafts), a handicraft is an object or product of community cultural identity, made by continuous manual processes, aided by rudimentary implements and some of mechanical function that lighten certain tasks. The basic raw material transformed is generally obtained from the region where the artisan lives. The mastery of the traditional techniques of community heritage allows the artisan to create different objects of varied quality and mastery, imprinting them, in addition, with symbolic and ideological values of the local culture [5]. Fonart declares as branches of Mexican craftsmanship pottery and ceramics, textiles, carved wood, pottery, metalwork, goldsmithing, jewellery, vegetable fibres, cardboard and paper, saddlery and leatherwork, lacquer, called maque, lapidary and stonework, Huichol art, work with shells and snails, glass and feather-work. It was not until the end of the Mexican Revolution, in the 1920s, when the social and political situation began to stabilize and the need of the governmental, artistic, and cultural sectors to provide the country with its own authentic cultural elements, that handicrafts were seen as an important sign of national identity. However, this affection for handicrafts, which seemed to give artisans a safe and hopeful alternative for the future by giving them recognition as true artists, was overshadowed by industrialized products, and by the hurried way of life to which consumerism that modern México brought with it. That deserved opportunity to give origin to the aesthetic and shape parameters that may have guided the line in the style and identity of Mexican design during the last century has been slow to arrive.

4 CURRENT SITUATION AND DISCRIMINATION OF ARTISANS IN MEXICO

The situation of the artisan population in Mexico is complicated. In 2019, handicrafts employed only 489,890 paid jobs [6]. This represents 0.39% of the country's total population of approximately 125 million people. According to the General Direction of Analysis and Prospective of the Welfare Ministry of the Government of Mexico, in 2008, 67% of the artisans were in poverty. It also indicates that 69.6% of artisans live in rural localities of less than 15 inhabitants and 44.1% speak an indigenous language [7]. This situation jeopardizes the continuity of handicrafts and Mexico's cultural legacy. Artisans living in poverty do not have the level of schooling that would allow them to efficiently calculate manufacturing costs and set a fair price for their products. Emma Zapata, from the Indigenous University of Mexico, indicates that the income artisans receive from the sale of their products is destined to cover the immediate basic needs of their families [8]. It is very common for artisans to travel from their communities to nearby tourist cities or state capitals to sell their pieces, walking through the streets, suffering from the harassment of people and the local police who prohibit them from selling on the street, which further undermines their dignity. Dr. Juan Pablo Aguirre Quezada defines discrimination as acts of segregation of different people based on gender, race, language, religion or other physical, cultural or social differences. These conditions prevent the individual from achieving full social integration, violating his or her fundamental human rights. [9] In Mexico, close to 7 million people of indigenous origin are likely to suffer some type of mistreatment, marginalization or rejection, due to their physical appearance or ethnic origin. The Mexican firm Gabinete de Comunicación Estratégica (GCE) conducted a survey indicating that 87.3% perceive a lot or very much discrimination in Mexico, and that the most discriminated social group is the indigenous people. The survey implies that the origin of discrimination is the lack of values, with 36.3%, lack of education, 32.3%, inequality in social classes 13.1%, prejudice 7.6% and the lack of laws that protect everyone equally 6.7% [10].

5 SOCIAL COMMITMENT AND VALUES OF GENERATION Z

The generation of people born between 1995 and 2015, many of whom are currently in college, has been frequently named as Generation Z. Its members are the first digital natives and do not remember the world without internet, iPod, iPad or iPhone. For this reason, Jean M. Twenge refers to them as the iGen [11]. More than any other generation, iGen'ers have had first-hand, real-time contact with the most relevant social, political, and climate change events in the countless sources of information they have access to. Many of these young people actively participate in their close circle, are well aware of the situations, but mainly take part in online discussions in their various social networks. Their consumption habits are influenced by their awareness of self-care, respect for the environment and concern for the right to diversity, inequality and social problems.

Young activists such as Greta Thunberg, Malala Yousafzai or Elijah McKenzie-Jackson, are a clear example of the ideals of this generation and are referents for the defence of justice and transcendent causes for today's world. I believe this group of people will be pivotal in the future of the relationship and co-habitation between artisans and handicraft buyers who, in addition to appreciating craft products per se, value their origin, respect for nature and the symbolism and culture that represent.

6 THE PROPOSAL

With the objective of fostering the co-habitation of artisans in poverty with people of middle and high socioeconomic level, to which our students belong and are those who can buy and participate in the design and marketing of handicrafts, the proposed model of inclusion is to allow artisans to take the position of university professors. Artisans directly explain their cultural background and later their techniques, but mainly, they will be personally involved with the students, stimulating an exchange of ideas and creative processes.

7 METHODOLOGIES

The Design and Handicrafts course was taught in the August-December 2022 semester to a group of 19 students. It was developed over 16 classes, one class of 3 hours per week, where the following topics were taught:

1. Introduction.
1.1 Taxonomy of the creative activities: typology of the arts, design and handicrafts.
1.2 Cultural heritage (tangible and intangible).
1.3 Analysis and interpretation of handcrafted pieces.
1.4 History and evolution of handicraft production in Mexico and the world.
2. Development of proposals.
2.1 Inspiration, research, management and context analysis.
2.2 Production of tests and experimentation of materials.
a) Cardboard and papier-mâché.
b) Metalwork and tin leaf.
c) Textile embroidery.
d) Saddlery and leather.
e) Carved wood.
f) Vegetable fibres, wickerwork.
2.3 Development of product proposals.
2.4 Production of final pieces.
3. Museography.
3.1 Design of museography.
3.2 Production of exhibition and museographic materials.
3.3 Development of communication materials.
3.4 Assembly.

The topics of point 1 were developed under a lecture scheme, where after the teacher's explanation, a debate was opened so that the students could express their points of view about the situation of handicrafts and artisans in Mexico. This, in turn, prepared them for the topics seen in point 2 of the course. Here they had the challenge of designing and handcrafting a piece with each of the techniques seen.

In order to select the artisans invited to the course, we gave preference to the most representative traditional techniques in the state of Querétaro, so that the students would have a closer connection with the local culture. The techniques selected were textile embroidery, saddlery and vegetable fibres, in this case, rattan. Subsequently, I approached to the two most important institutions in the protection and promotion of handicrafts in the state. CEDAI, (Artisan and Indigenous Development Center) and Casa Queretana de las Artesanías, (Queretaro House of Handicrafts). Both government offices offer artisans spaces for the sale of their products, organize workshops and contests to promote good quality.

For the textile embroidery technique, we invited artisans Remedios Vázquez and Daniela Ruíz, from the municipality of Amealco. To teach the saddlery and leatherwork technique we had the participation of the artisan Yarizel Olvera, from the municipality of Cadereyta, and for the weaving technique with vegetable fibres (rattan) we invited María Refugio Asunción Cruz and Manuel Jiménez.

All of them had an independent 3-hour session that was organized as follows. First, (30 min) they talked about the origin of the technique in their community, its origin and symbolism and how they inherited it from their ancestors. Secondly, (60 min) they explained the artisan technique, for this, it was necessary to previously buy and prepare the raw material with which each one of the students followed the instructions of the master artisans and elaborated a simple product to learn each one of the techniques. Finally, the artisans oversaw advising the students face to face to have a direct contact between them.

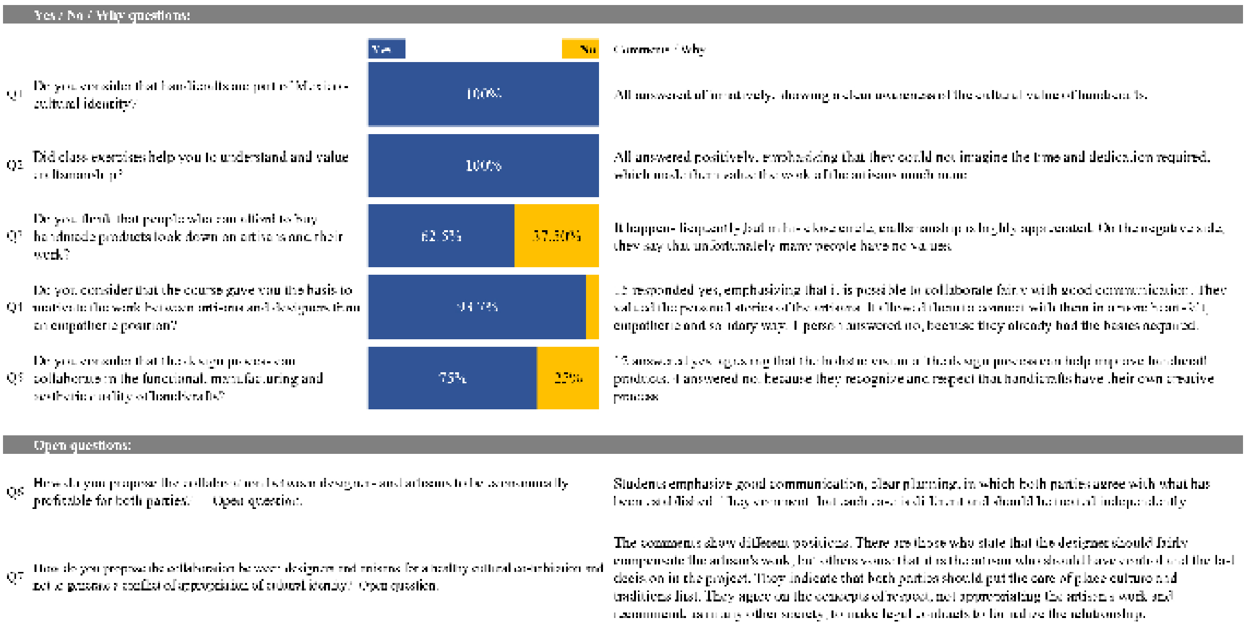
Since it was the first time that the students had contact with the techniques, they were not able to finish their piece during that session, so they could finish it during the week and present it in the following session. When presenting their work, students explained the expressive concept of their pieces, and how they had reinterpreted what the artisans had taught them. In this way, the students were allowed to have their own point of view and take responsibility for justifying it.

With the techniques learned during the semester, as a final delivery, the students designed a collection of pieces that expressed a personal statement about fashion, where they were able to combine materials and techniques according to their needs and requirements.

In point 3, curatorial and museography topics were taught, and with the active participation of the students, we designed and prepared an exhibition of the final projects, which was presented at the Museum of the City of Queretaro. The students participated in the museographic assembly of their pieces.

8 RESULTS

At the end of the semester, 16 of the 19 students enrolled responded to a survey, that showed the following results:



9 CONCLUSIONS

During the semester, and with the development of each of the topics and techniques seen, I could notice that the students gradually became involved in the problems and social situation of the artisans. They showed their interest in the cultural heritage of the communities, trying to understand the origin of the sources of inspiration that each technique represents.

One of the most provocative points in the final comments was the great manual effort that craftsmanship represents. Having made each piece with their own hands, showed them that the price at which artisans sell them is not fair.

It is interesting to find comments that say that it is the artisan who should have control and authorship of the project, be the one to request the services of the designer to help him/her resolve technical issues, which from my point of view, is a sign that the course sensitized the students, breaking any barrier or colonizing posture.

The exchange of ideas and personal involvement created an atmosphere of empathy that can considerably lessen discrimination. Students listened to the problems of the artisans and felt able to help them by proposing design and marketing strategies. The artisans felt empowered as they shared their knowledge with the students. They identified themselves as transmitters of the culture and heritage of the indigenous peoples, of whom we are very proud.

I am confident that by repeating this model in this and other subjects, future designers will continue to develop the empathy and cultural co-habitation skills that Mexico and the world need.

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EXPLORING THE IMPACT OF LINEAR & NON-LINEAR PRESENTATION METHODS IN A DESIGN HISTORY COURSE

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ABSTRACT
Design students are well-versed in standard linear presentations: moving from slide A to B to C in a predefined order. However, they are unpracticed in non-linear storytelling in the classroom, a method that allows for narrative flexibility. This paper explores the impact of linear and non-linear presentation methods using linear and non-linear presentation software Canva and Figma in a Design History course. Eighteen design students from gaming, user experience, graphic, and industrial design disciplines participated in the study. Students made five class presentations, twice using Canva and twice using Figma and for a fifth collaborative presentation, they could choose either tool to present with. They were encouraged to experiment with linear and non-linear methods of presenting to the class.
Results indicate that Figma had a steeper learning curve than Canva; however, its non-linear structure more effectively engaged the audience, increased knowledge retention, and improved opinions of team presentations over Canva's linear structure. When asked which presentation tool to use in next year's course, 50% said Figma, 11.1% said Canva, and 38.9% said both. Disrupting the current linear based standards for design presentation tools, like Canva or PowerPoint-type products, with non-linear methods with tools like Figma enhances student learning experiences. Students also preferred presenting alongside a partner, enabling increased discussion of details and deeper exploration into critical aspects of the designer's lives.

Keywords: Design education, Figma & Canva presentations, product design history, dialogic teaching, studio-based pedagogy

1 INTRODUCTION
Students are well-versed in standard linear presentations: moving from slide A to B to C in a predefined order. However, they are unpracticed in non-linear storytelling in the classroom, allowing for narrative flexibility. Exploring the use of linear and non-linear presentation methods in the classroom and their impact on student learning warrants study. Pinker teaches that presentations should go beyond simply transferring data and facts and become a dynamic, world-making relationship between creators and audiences [1].
Linear presentations using software such as Canva (an online tool with ready-made templates) remain prevalent in design education settings and reflect historic industry standards. Non-linear presentations, on the other hand, reflect contemporary website technology and narrative development. Prosser argues that non-linear structures effectively foster personalized learning environments [2]. In addition, Liu indicates that non-linear digital storytelling might create collaborative learning environments [3]. Non-linear structures have also been shown to examine the subject in more detail, carefully considering different points of view [4].
Figma, a collaborative web application for interface design, has become a leading force in non-linear narrative development. Figma's motion capabilities and audience interactivity has encouraged explorations into how students might use it as a classroom presentation tool. As Figma gains popularity in professional settings, investigating how this technology could effectively support meaningful learning and presentation experiences in design education is worth exploring.

This paper researches the impact of linear and non-linear presentation methods using Canva and Figma software tools in a design history course. The course introduces students to the software and encourages them to experiment with linear and non-linear techniques of presenting the designers they study. Surveys administered to students at the middle and end of the semester assessed the impact of these tools on student learning and presenting experiences and knowledge outcomes.

2 METHOD

2.1 Participants

Participants included eighteen students from four design disciplines, graphic, user experience, gaming and industrial design. Nine females and nine males participated in the study. Participants were informed that the presentation software used to create, present, and disseminate their work would be switched for two class presentations, and their experience with the new tools would be evaluated. All participants were undergraduate students at Brigham Young University. Participants received no extra credit or compensation and could withdraw from the study at anytime.

2.2 Study One – Canva

Students are assigned to conduct research on assigned historical or contemporary designers and create a 10–15-minute class presentation that includes facts about the designer's life and training, images of their work, an explanation of their design philosophy, a video link if available, and examples of how the designer influenced contemporary design, as applicable.
Students were provided with a 10-page Canva Design template, as shown in Fig. 1, formatted for use on Instagram. Since January 2018, students have posted their presentations on the course's Instagram account, HistoryofProductDesign@BYU. The template, presentation content, and posting details are explained in a previous publication [5] and have evolved yearly to add clarity and structure.

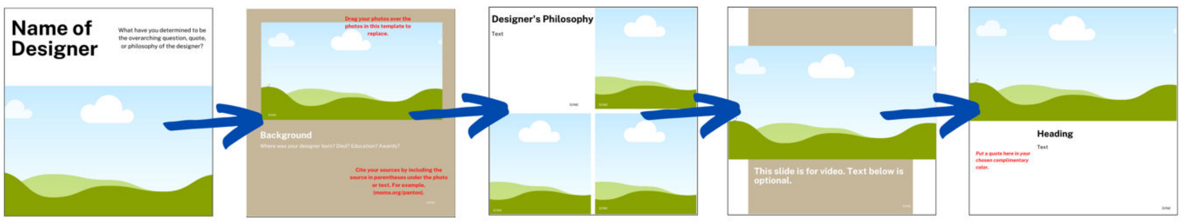

Figure 1. Linear Canva Template

The course utilizes a corporate Instagram account, allowing researchers and students access to Instagram's analytics tools which track total accounts reached, engagement, top cities and countries, quantified post engagement, and the audience's age and gender.

2.3 Study Two – Figma

The content expectations for study two were identical to those in study one. Most design students were moderately familiar with Canva as a simple-to-use presentation tool but were unaware of Figma as a presentation tool. Figma is optimized for prototyping web page interactions and allows for immersive, custom, non-linear presentations.
Two student research assistants worked for 20 hours creating a 3x3 square presentation template on Figma that students could copy and insert their designer's information in whatever order they chose. See the home grid in the centre of Figure 2.
The template structure encouraged interaction with their audience in a non-linear manner. Presenters could choose themselves or ask the class audience which content square they wanted to view on the grid, thus giving the audience power to experience the information based on their chosen interests [6].
Figma also allows greater slide customization. In contrast to Canva, Figma does not constrain students on the number of images used on a single slide through the use of carousels. Figma's ability to present multiple levels of motion also adds a non-linear element to the presentations. Incorporating Figma in the classroom as a presentation tool allowed the audience to engage personally with the presenter and the information.

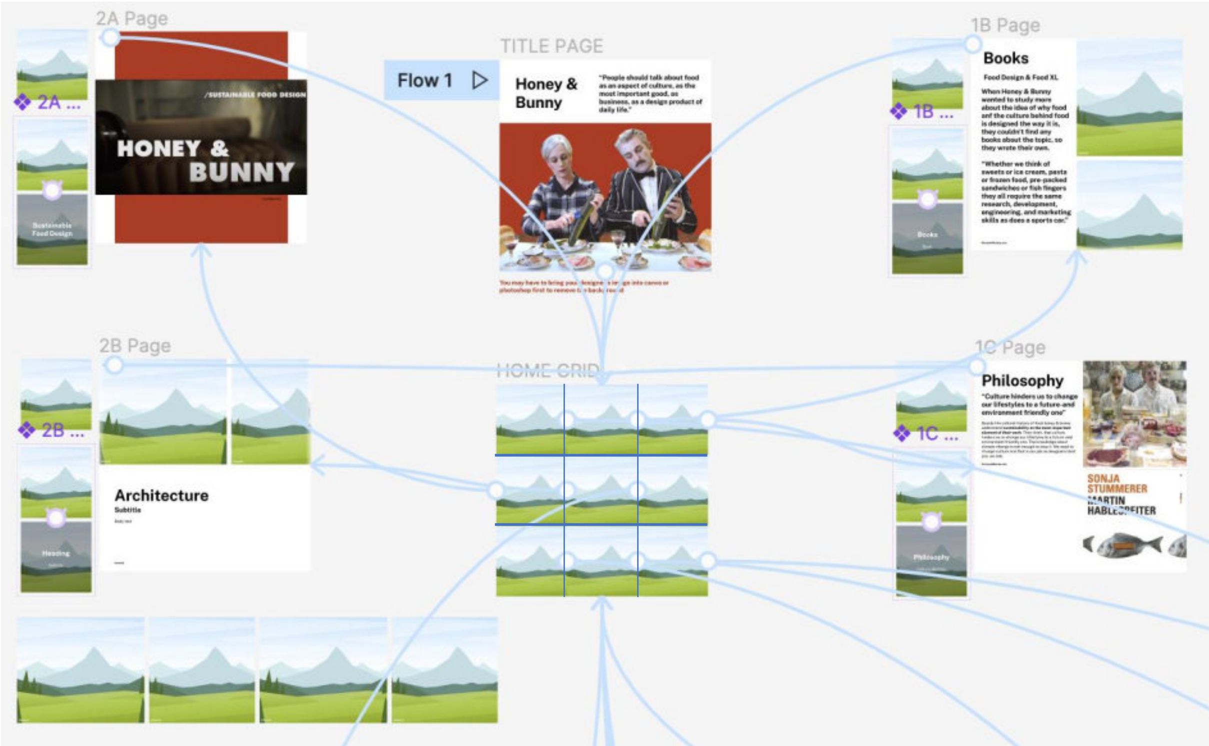

Figure 2. Non-Linear Figma Template

2.4 Procedure

Students researched, built, and presented five different presentations roughly two weeks apart over the semester. The first two presentations were created in Canva and posted on the class's Instagram (Study 1). For the second two presentations, students learned the basics of Figma and posted the results on Instagram, which unfortunately does not enable non-linear presentations. However, students were encouraged to share their Figma presentation on their LinkedIn profile, thus allowing an external audience to experience their non-linear presentation experience.

For the fifth presentation, students presented in pairs and chose to present using Canva or Figma. Most students decided to use Figma instead of Canva for their final presentation.

Researchers administered a digital survey via Google Forms in the middle and at the end of the semester, which took about 15 minutes to complete.

2.4.1 Study One - Canva as an Educational Tool

Survey one reviewed the use of Canva as a presentation tool. Students were asked about their presentation creation experience, how familiar they were with the tool, the learning curve for Canva, the advantages and disadvantages of Canva over other linear software tools, and the effectiveness of the course template. It also explored how well the Canva based presentations helped them understand the design philosophies of the individuals studied.

2.4.2 Study Two - Figma as an Educational Tool

Survey two reviewed the use of Figam as a presentation tool. Students were asked about their previous experience with Figma and how easy it was to use as a presentation tool. Students were asked about the advantages and disadvantages Figma has over Canva or other presentation software and collaborative presentation creation with a peer. Students were asked for software and joint presentation recommendations for future classes.

2.5 Data Analysis

The results of the two surveys were assessed to understand the impact of the changes made and the overall influence of the course and its structure on the student learning experience.

3 RESULTS

The sections below will discuss the quantifiable data and shared comments on class presentation tools and material dissemination from the two surveys. Numeric responses are given based on either percentages or a 10-point scale.

3.1 Study One

When asked about learning how to use Canva, 87.5% of students said it was very easy, with 70% claiming ease of use as Canva's most significant advantage as a presentation tool. Students qualified that by saying Canva had readily available tools and accessories to design their presentations easily. Although students enjoyed how intuitive Canva was, most felt the tool restrained their creativity. One student stated, "Canva doesn't seem to have quite as much depth as could be useful once a basic understanding is acquired. I felt a possible discouragement from digging too deep for fear of finding the bottom of its capacity." Despite feeling creatively restrained, nearly 75% of students said they would use Canva as a presentation tool in the future, with 43.8% of students saying they would use it as their primary presentation tool.

Students were provided with a template to use for their Canva presentations. When asked what changes students would like to make to the template, the vast majority claimed that no changes needed to be made, with only 25% wishing they could have more creative liberty within the template guidelines. When asked whether or not the content instructions were helpful in framing and building their presentations, 68.8% of students believed the provided instructions were helpful.

The second portion of the survey addressed students' understanding and retention of the information from the presentations. When asked how well the linear (Canva) presentations helped students understand the design philosophy of the presented designers, students replied with an average of 7.9. When asked how much historical designer knowledge was retained, students answered with an average of 6.3. When students were asked what would improve the quality of the presentations so they would retain more knowledge, the majority said the presentations lacked classroom engagement. Some students claimed that linear storytelling deprived the class of engaging with the material and presenter. One student stated, "It feels like we are presenting the Instagram posts rather than using the slides to help tell a story. Engaging stories need pacing, and our presentations feel a little one-speed and usually only invite us to think when the discussion opens afterwards." Other minor improvements students suggested were two-person presentations, building diagrams connecting the designers, and a less strict presentation format.

3.2 Study Two

In contrast to Survey 1, when asked about learning how to use Figma, 50% of students said it was difficult, with 61% claiming the steep learning curve as Figma's most significant disadvantage as a presentation tool. Students qualified this by saying that if they were not given a presentation template, they would have been lost when trying to use Figma's different tools. Although some students struggled with learning Figma, 93% said they would use Figma as a presentation tool in the future, with 16.7% claiming they would use it as their primary tool. When asked about the advantages of Figma, several students noted that they enjoyed the motion abilities. One student claimed they liked the idea that one slide is not stagnant, which causes the presentation to be viewed as a never-ending story. Students claimed the interactive elements made each presentation more lively and engaging. One student stated that Figma allows for more diversity in what you can do, which makes it stand out as a platform in comparison to linear presentation methods such as PowerPoint.

The second portion of the survey addressed students' understanding and retention of the information from the presentations and working alongside a partner. When asked how well the Figma presentations helped students understand the design philosophy of the presented designers, students replied with an average of 8.3.

When asked how students would rate working alongside a partner when presenting, students answered with an average of 6.8. Most students preferred working with a partner because it took less time, was fun to work with someone, helped mitigate procrastination, and could dive deeper into specific topics because they were delegated between the two students. Some adverse effects of group presentations included disagreements on presenting, lack of proper communication and coordination, and unbalanced delegation of tasks.

3.3 Canva vs Figma Preference

When asked what presentation method students would recommend for next year's group, 50% said Figma, 11.2% said Canva, and 38.9% said both. Many students believe Figma should be the main presentation software next year because they believe it is a more valuable tool to learn for future design careers. Several students claimed they would also like Figma to be the sole presentation method because they would understand it better if it were solely used during the semester. Students also argued that Canva has an easy learning curve, making it unnecessary to learn in a classroom setting when it could be learned quickly outside the classroom. The students who believe Canva should be the primary presentation tool argued that Figma is not nearly as compatible with social platforms. While Figma is an excellent tool for design, it is not the best for presentations. Some students also preferred Canva because it is an easy tool to use so that they could focus on the content of the presentations over the design. The students who liked both presentation methods argued that comparing and contrasting the programs is valuable and helpful for the future.

4 DISCUSSION

4.1 Canva

Canva was an easy but limiting platform for students to use as a presentation method. Most design students were familiar with Canva and found its capabilities limiting. While the ease of use appealed to students, they felt restricted creatively with the provided template and believed the capabilities weren't as engaging when presenting to the class. These results affirmed a need for more customization and engaging features for the students to tell their stories. Students yearned to tell a story based on their research and use their existing design skills to design their story further. Although students felt the template was sometimes limiting, they enjoyed the ease of transferring content from Canva to Instagram. The linear storytelling of Canva proved to be more compatible with current social media layouts.

4.2 Figma

Transferring the class to Figma as a presentation tool proved to be a steeper learning curve. Most participants responded that learning the new software was very challenging as a presentation tool (study 2); however, Figma served them in crafting more engaging stories. While both Canva and Figma had pre-made templates designed for the students, Figma allowed students to be more creative in crafting presentations due to its personalization capabilities and moving parts which assisted in the storytelling process. Figma became the class's preferred method because they valued learning new software with moving features. Figma's non-linear style also proved to help students retain information better. Figma rated higher than Canva in understanding the designer and the designer's philosophies. One criticism of the Figma presentations was that there was a lost opportunity by not having students use their phones to interact with the presentation as it was being presented.

4.3 Future Class Use

The survey responses led to a deeper understanding of improvements that could be made in a future course. A point brought up on numerous occasions was that the software used should depend on the desired outcome of the course. If the class is structured in hopes that students will learn useful software for their careers, Figma may be the better option. However, if the presentations are focused on the content as opposed to the presentation method, Canva may be the better option due to its ease of use. One criticism of this course is that while students valued the templates for design purposes, they believed the content instructions needed alterations. An alteration could include providing a list of potential topics to cover in the presentations but allowing students to determine which topics best suit the narrative for their designer.

Lastly, most students preferred working alongside a partner and mentioned that it allowed them to focus on specific aspects of designers in depth. Collaborative presentations also encouraged students to speak with another individual about their designer, resulting in greater knowledge retention from that particular presentation. This outcome informs that the future class structure should consider more collaborative opportunities.

5 CONCLUSION

Overall, the outcome of the course can be expressed through two student survey results:

"Figma offers much more control over movement and presentation flow; the presentation can adapt as it's given, where linear presenting must be presented in the planned order."

"If you want 'presentations' and posts on Instagram, they will turn out much nicer when made in Canva. The things that make Figma great for engagement make them horrible Instagram posts (no scrolling or interactions makes the information inaccessible in jpeg form), and the things that make good Instagram posts make for boring Figma prototypes (no scrolling/interactions - you might as well use Canva)."

Based on our analysis of the classroom surveys, disrupting the current linear based standards for design presentation tools, like Canva, Adobe, or PowerPoint-type products, with non-linear methods using tools like Figma enhances student learning experiences. This replicates Maleki's findings that class attention, growth, motivation and participation were greater using non-linear storytelling over linear methods when teaching English for medicine [7]. As content dissemination methods continue to evolve within the design world, the culture and methods of classroom presentations will eventually reflect those changes.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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WHAT IS 21ST CENTURY DESIGN EDUCATION AND ARE WE DOING IT WRONG?

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ABSTRACT
Designers are entrusted with increasingly complex challenges and the stakes have never been higher. The complex, risky and impactful endeavours of modern design reach far beyond the technical constraints and commercial rewards experienced by previous generations; now designers are expected to shoulder the burden of global challenges (e.g., the SDGs), to deal with complex human behaviours and societal concerns, plus the impact of the Anthropocene crisis, whilst navigating (and advocating for) new technologies and the erosion of traditional fields of practice. This is a model of practice where designers are shapers of society, activists and agents for change, rather than service providers. Despite the popularity of television shows that depict design as an aesthetic practice, design is no longer simply about 'making things pretty' or 'making it work better', cheaper to make, nicer to use, or more desirable, although there is still gainful employment in those missions.
In design education, does an over-reliance on traditional skills and artifact production expressed through striking graduate exhibitions, work to the detriment of graduates and the profession, masking the urgent need for a comprehensive review of what, and how we teach design, and why?
This paper aims to provide a critical provocation, seeking to understand the constantly evolving paradigm of design practice, to identify required graduate attributes and models of curricula and pedagogy that ensure that graduates are prepared and armed with the appropriate skillset for future global practice. Is design education still fit for purpose, or are we doing it wrong?

Keywords: Design education, design practice, future focused pedagogy, design futures

1 INTRODUCTION
Designers are entrusted with increasingly complex and impactful challenges [1]. Contemporary design practice is moving from a model where the designer is at the subjective centre of design decision making, involved primarily in artifact creation, to that where the designer is both an activist and facilitator contributing critical know-how to the design of socio-technical systems.
Designers are now expected to shoulder the burden of global challenges, to deal with complex human behaviours and societal concerns, whilst navigating new and emerging fields of practice, and advocating for new technologies and more responsible, ethical and sustainable practice. A model of practice where designers are shapers of society, activists and agents for change, rather than service providers.
Designers are challenged to deal with socio-technical 'wicked problems' that introduce a new level of difficulty and complexity, requiring adaptability to transition across traditional practice boundaries with new interdependencies and interactions. And the role is not merely responding to a client brief, instead designers are now required to work in an ambiguous pre-brief environment, where rather than problem solving, the designer is involved (and/or leading) problem identification and envisioning critical interventions. This requires competency in systems thinking, a well-established understanding of human behaviours and societal and cultural customs, and a design methodology that employs high level critical awareness and thinking, in addition to more traditional creativity and skills-based acumen. Our graduates need to understand complex systems, not just user needs and manufacturing.
Does design education meet these needs, or is it still anchored in a curriculum and pedagogical model that aligns more with the Bauhaus and Ulm school tradition, which although transformational at the time, may not fully address the needs and challenges of 21st century design practice? Are we still focusing on traditional core (artisan) skills (making, drawing, artifact production, etc) or we developing critical thinkers who are adequately prepared to deal with complex scenarios that require not new

products, but a radical societal shift and new behaviours? Do our design projects build cognitive and intellectual abilities, or do they propose more artifacts or services? Should we be focusing more on a non-outcome based approach to design education? Does design curricula create opportunities for Epistemic Freedom or does the Eurocentricity focus of design education continue to be limiting and inhibiting (impacting diversity), and self-perpetuating? Does the current model of design education adequately prepare graduates for the complexities of future practice in a world where we acknowledge, respect and value alternate knowledge systems, address equitably the needs of all global citizens, and protect diverse cultures and contexts with societal and environmentally sustainable solutions? Or do we need to transform design education to meet the needs of a contemporary world in crisis?

2 THE EVOLUTION OF DESIGN

Tonkinwise [2] refers to the 'orders' of design practice, where design practice evolves from craft and a tradition of producing useful goods for people (1st order), towards domains of design for services (2nd order) and design for social innovation (3rd order), with change-oriented design or Transitional Design the 4th order, where a number of discourses including ecosystems science, sociotechnical innovation, and life changes (social psychology) are established. Indeed, it is apparent that we have moved from a client-centred and product manufacturing-centric model, in which designers contributed to mass consumerism, over-consumption, and consumer engineering, to a more considerate user-centred practice, with sustainability and closed loop deliberations, to designing experiences, to challenging established narratives (speculative design), towards a future of high-level complexity and systems level interventions. And now, designers are expected to "deliver 'emergent possibilities' within problem contexts, as opposed to imposing pre-planned and resolved solutions upon a situation" [2].

2.1 Design responsibilities

Advocating for reform from within design practice and demands for the pursuit of social change through design, are now ubiquitous. Alistair Fuad-Luke [3] claimed 'design activism' as an emerging practice in which designers are using "the power of design for the greater good," asking "could the creation of well-being and not goods and services, be a new purpose for design?" Manzini [4] describes designers as facilitators, as triggers for new social conversations, and also as design activists proactively launching socially meaning design initiatives [5]. The WDO definition of Industrial Design [6] as "a strategic problem-solving process that…leads to a better quality of life" also points to greater expectations for design. Designers are now expected to lead critical discourse and creative practice as "facilitators of a system of value co-production" [7] to realise new meanings for societies and cultures, but with the caveat that *"design is not a magic bullet, and we are not the owners of the gun*" [8].

2.2 A new generation of designers

"From disruptive technology to disruptive ideas, the early decades of the twenty-first century can be characterized as a period of non-conformity and new direction" [9]. The next generation of designers are driven by a social conscience and highly concerned about the world they will inherit, with climate change and societal inequality, key concerns. Even these nascent designers are aware that design can no longer be an instrument of consumerism. These students have grown up in a world where the negative impact of global forces is increasing apparent, and societal injustice is more blatant, especially with global connectivity allowing greater access to information not filtered or censored by governments, nor interpreted with bias by self-serving media organisations. This is a generation whose values are less deferential to historical social conventions, who expect their education to empower them to co-design new solutions to global challenges in the most sustainable, culturally sensitive and ethical manner.

3 CRITICAL CONCEPTS FOR DESIGN FUTURES

There is an acceptance that designers typically only design for the wealthy 10% of global communities and those in less affluent developing economies (also known as the other 90% in the Base of the Pyramid model), are less likely to benefit from design, but instead suffer the consequences of globalisation and design-led consumerism, specifically exploitation, resource depletion, pollution, the impact of climate change, and societal and economic inequalities. Criticism of design practice and its role in driving harmful consumerism and 'dangerous' overconsumption e.g., Papanek [10] has persisted for many decades, and whilst design has responded with increasingly sustainable and responsible practice, for many communities design is viewed as an predominately aesthetic practice, producing artifacts for the wealthy. Unfortunately, the adjective *designer* is now synonymous with *expensive*. Design specialist retailers and brands have sustained this perception with 'designer' products typically sold at vastly inflated prices that bear no relationship to the manufacturing cost, (unlicensed replicas have revealed the real price), creating an elitist sub-culture that values brand, purchase price and prestige, over value. This upmarket consumerism devalues the potential of design to make a broader contribution, diminishing its credibility, and alienating the communities who would most benefit from design intervention. This is not to diminish good product design, which makes a significant contribution to our lives and wellbeing, but the commodification of famous designers (e.g., Eames, Noguchi, Jacobsen, Mies van der Rohe) is undemocratic and alienating; good design should be accessible and affordable for all.

It is evident that design must transition (both in practice and perception) from *invention* to *intervention.* The design profession has a more valuable contribution as an agent of change, acting as provocateur and disruptor, whilst facilitating co-design processes that create opportunity, enhance societal wellbeing and empower stakeholders. And this necessitates a reframing of the practice of design, repositioning it as a profession that is both willing and sufficiently skilled to tackle complex global challenges, especially in a post-Anthropocene future. In addition, design requires a far more diverse participation, at present its prevalent Eurocentrism diminishes design's relevance and value to many global. communities.

3.1 The influence of design?

Parker [11] states that "designers need to assert with greater confidence the distinctive value they can bring to strategic design." But Meyer and Norman [1] note the lack of designers in high-level positions within organizations and government, pointing to the need for a broad, informed knowledge of a wide variety of topics and understanding of modern societal issues, modern ethical concerns, declaring that designers must understand rigorous argumentation and the value of evidence, and must put the needs of the organisation, or society, above the needs and views of any single profession – an area where design has previously been unsuccessful. This is not about discarding core design principles; it is about enhancing the skills that are so central to the design discipline and using them in more open and participatory ways to expand our practice. Design should not be defined by the *form* of the solution, but by the *impact* of the design intervention. Design practice needs to be framed around the role of the designer to facilitate solutions to complex problems, and this will need an enhanced skillset and an ability to work in an integrated and systemic manner, far removed from the craft of artifact production and the celebration of design as independent practice. Is this reflected in design curricula?

4 A CRITIQUE OF DESIGN EDUCATION

There have been many calls to redesign design education, and these derive from different questions, contents and motives. What is apparent is the need for evolution, to include new perspectives and knowledge systems, to prepare graduates to understand complex societal issues, to work outside normal design practice domains, to utilise organisational strategy, and to make impactful contributions in response to global challenges. Loy [9] notes that "*design education should not align itself with entrenched, complacent ill-prepared academia"* and that a rebellion is required for design learning to remain relevant, shouldering its responsibilities in both preparing the designers of the future, and challenging norms of practice. A tension also exists between the responsibility to impart graduate level employability skillsets, and the need to educate future leaders who will reshape their profession.

4.1 Decolonising the curricula

There is a growing movement to question the ethnocentric nature of design education [12], with many linking design education's political and social contexts to large industrial economies. As noted earlier, the design industry is represented predominately by the affluent and Eurocentric, and student cohorts in design education in western countries similarly are not particularly diverse. In the UK, HESA data shows that black, Asian and minority ethnic groups are significantly under-represented comprising 15% of design students, with less than 5% of these are from black Caribbean or African backgrounds [12]. Curriculum and pedagogy can play a significant role in this, with recent educational initiatives such as *decolonising the curriculum,* long overdue. The acknowledgement and valuing of alternative knowledge systems, and the cultural respect that occurs with that, not only adds significant value to design education and practice but facilitates a process where western bias is diminished in the curricula, making design more appealing to non-traditional students from diverse backgrounds. Whilst this does not (as some may fear) mean discarding traditional design knowledge, it does require "delinking design culture from its Eurocentrism and rooting it in local issues, cultures, and identities" [12]. Noel [13] talks of Epistemic

Freedom - *the right to think, theorize, interpret the world, develop own methodologies and write from where one is located and unencumbered by Eurocentrism* – noting that Eurocentricism and *western exceptionalism* is dominant in design curricula, and that this does not provide agency for people who do not see themselves, their worldviews, and their ways of knowing and being, in the curriculum.

4.2 Definitions of practice

It can also be argued that the narrow and traditional 'technical – design for manufacture' definitions of industrial/product design are limiting its appeal as a career choice, and that a *reframing* of practice by professional and regulatory bodies could have educational recruitment implications. If our practice was represented by social innovation, sustainability and strategy rather that mass manufactured products, would design resonate more strongly with young people driven by a social and environment conscience? Could such a reframing enhance gender, ethnic and class diversity amongst the student cohorts?

4.3 Non-traditional career pathways

Graduate employability data from both Australia (DIA) and the UK [14] indicates that 75% of design graduates go into non-traditional areas of employment (with only 25% going into design consultancy or R&D manufacturing roles). Yet most design programmes still offer curricula that is constructed to prepare students solely for traditional employment pathways. Whilst those graduates going into other fields of employment are still empowered by their creative thinking, human-centred and problem framing /solving skills, are their alternative career pathways considered in the design of curricula?
It can also be argued that many universities have a 'laissez-faire' approach to graduate employment; whilst developing *employability* is a key educational agenda, most institutions leave it up to individual graduates to define their career path, secure employment and adapt to change. Whilst pathways to traditional employment are relatively straightforward (and supported by institutional links with the design industry), how do we support the other 75% of our graduates as they establish careers in non-design environments? Are they sufficiently prepared and confident enough to understand and promote their value, and to meaningfully contribute in areas where design has previously been unsuccessful?

4.4 Post-disciplinary design

It is critical that that curricula and school/programme structures are not limiting the vision and capability of graduates. The traditional *silos* of design disciplines prevalent in design education, whilst adequate for traditional vocational training, may not adequately prepare students for post-disciplinary design practice. If we accept that the role of design is increasingly to create value at the intersections of organisational disciplines, then designers not only need to think and act in more fluid, autodidactic and creatively optimistic ways [15], but also to stop self-identifying within narrow practice parameters. In a post-disciplinary context, designers need to identify as creative and strategic thinkers, and not limit or define themselves by specific and traditional outputs. However, practice boundaries have proved useful in design education, to allow students to focus and specialise, and to avoid producing generalists who may not have the specific skills and knowledge to gain employment and meet employer expectations in graduate level positions. How in the limited timeframe of an undergraduate design degree programme, do we balance these tensions, to deliver such comprehensive graduate attributes, for now and the future?

5 TOWARDS A MORE PROGRESSIVE PEDAGOGY

It is apparent that a new approach to design education is required, so what and how should we teach? What are the values and attributes that we need to instil in our graduates? Designers need to be sustainable, responsible, ethical, socially focused, develop a strong understanding of human behaviours and organisational strategy, and have the confidence and acumen to deliver impactful and strategic practice, rather than merely provide a service. Design is at its most valuable and influential when it is engaged at the strategic problem discovery stage, rather than responding to a prescriptive client brief.

5.1 Aims

The aim of any educational model at its most basic is to deliver appropriate skills and knowledge that allow graduates to succeed in their chosen profession. However, at a higher level, design education cannot be seen as vocational training, we have an educational responsibility to not only deliver technical competency and creative capability, but to instil a set of values and characteristics that will define their future practice, including self-efficacy and advocacy, confidence, adaptability and resilience, critical thinking and reflective practice. To deliver graduates who will redefine the role of design, taking design practice into new realms of possibilities, and impacts. We can anticipate some of the responsibilities the next generation of designers will face; but how do we prepare them for those challenges?

5.2 What we should teach

Contemporary concerns have changed the emphases in design education, focussing on the capability of designers to make a positive societal contribution, through user cultural and environmentally focussed themes [5]. Our curriculum must ensure they are well prepared for practice in design for social impact, design for health and well-being, design for sustainability, experience design, interaction design, service design, systems design and strategic design. It is essential that graduates are well versed in these new and emerging areas of practice, with an appreciation of values (human, societal, cultural), respect for alternative knowledge systems, and a socially focused, responsible and ethical approach. To add value in employment outside of design industries, they would benefit from learning strategic thinking, forecasting/fore sighting, organisational management, behavioural psychology, and entrepreneurship, and developing acumen in influencing and persuasion, codesign/cofuturing, and behavior change.

5.3 Graduate attributes

Whilst it is essential that we teach the fundamental skills and knowledge that will serve to secure graduates their initial employment, our responsibility is to deliver graduates to industry who are prepared for future practice and primed to lead their professions into new and uncharted areas of practice. For this they will need robust processes to drive creativity and innovation, well-honed critical thinking for design, a reflective practice and a methodology that accepts and values alternate knowledge systems and different cultural perspectives. They will also need a robust, human centred, non-Eurocentric design perspective, and be comfortable with new and emerging areas of practice. They will need to be capable of operating effectively, and with influence, outside of traditional design practice, to advocate for, and extend design practice into other spheres of activity; organisational, strategic and policy. And they will need to be coherent and convincing storytellers, activists, and agents for change.

Graduates must be ready to operate outside their professional boundaries in post-disciplinary practice. For this, they need exposure to emerging and non-traditional practice areas, be highly skilled in design for digital futures (virtual, augmented, immersive etc), adaptable and post-disciplinary thinkers.

5.4 How we should teach

The next generation of designers are very different learners from previous generations. Additionally, as discussed earlier, designers are expected to navigate diverse explorative futures, where an agile skillset is being applied to increasingly complex wicked problems. To achieve the desired graduate attributes, design education must move from the traditional master-apprentice model to a learner-centric model (with students as partners), shifting the power balance to ensure student empowerment and ownership of the learning journey. This can be achieved through active engagement, self-directed learning and establishing student agency at any early stage. It is useful to develop a social construction of learning using the design studio pedagogical model to build trust and confidence, and to socialise assessment (self and peer) to make it a learning experience, rather than an authoritative grading paradigm. It is important to respect and develop the students' individual design identity, and facilitate personalisation and customisation of the curriculum, and their individual learning journey.

5.5 Redefining the design project

In design education, the design project serves solely as a vehicle for student learning, yet it is too often quantified on the aesthetic and technical quality of the outcome. However, one must question whether it is appropriate for design lecturers to be prescriptively directing the project journey and the outcome; should we just be providing the parameters and guiding and supporting students appropriately? Design projects should be open ended and ambiguous, requiring students to respond to scenarios and challenges, without predetermined outcomes. We need to replace artifact-focused curricula and prescriptive design briefs, which stifle creativity through inbuilt parameters and constraints.

Project briefs should afford students the agency to use research and ethnographic processes to explore the context, understand the users and other stakeholders, identify prevalent behaviours and areas of concern, and then define the problem to be addressed through an appropriate design intervention. This model requires lecturers to present a large and complex scenario/societal issue (e.g., how to enable an

ageing workforce?) and allow students to scope the project down to a manageable and distinct problem, and then define the parameters of their project journey and design intent.
Such design projects require students to assume a leadership role, rather than merely responding to a set problem or a directed outcome. Initially this approach can be confronting for those who are more comfortable with well-defined design briefs, however it also empowers students to work in a more holistic manner, to develop their own methodology, and to take ownership of both the design process and their own learning journey [16]. Not only does this facilitate unexpected project journeys and outcomes but has also proved valuable in preparing graduates for undetermined future practice. Graduates need experience in both navigating the 'wicked problem' space and working effectively in non-design environments. They must understand the value of design and how to use their skills to make meaningful contributions – this may not be in artifact production, but in facilitating users and other stakeholders through a co-design process, assisting governments and corporations to develop policies, strategies and services, and decoding behavioural patterns and developing behavior change models. Engaging students in partnered studio projects with external partners (industry, community, government agencies) enables familiarity with those processes, building confidence and proficiency.

6 DISCUSSIONS

In future practice, designers will need to be agile, interdisciplinary creative thinkers who confidently explore poorly defined problems and complex scenarios and societal behaviours, and then deliver innovative solutions. Does current design education instil the required values, or are we doing it wrong? This paper intends to serve as a provocation, to stimulate conversation, to question whether the design education models that have served us so well since the Bauhaus, are still fit for purpose.

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TRANSFORMATIVE LEARNING AND SUSTAINABILITY EDUCATION FOR GLOBAL CO-HABITATION

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ABSTRACT
As global societies face increasingly complex sustainability and environmental challenges, Higher Education Institutions must make appropriate changes in their policies and strategies to prepare for the demands of the future. This paper explores the potential of Design and Design Education to serve as catalysts for addressing many of the global issues currently affecting our planet. To exploit this potential, we need to transform the current educational paradigms that have been shaped by traditional discipline definitions. In pursuit of such ambitions, it is essential to shift towards learning models that enable us to create a sustainable and sustainability-focused learning ecosystem to foster a culture of reflective and informed innovation. A strong narrative is emerging from a broad base of literature around the need to shift from a tradition of disciplinarity to one of increased trans-disciplinarity. HEIs need to consider developing more relevant frameworks for coordinating and creating new disciplinary, interdisciplinary, and transdisciplinary approaches to inform both teaching and research. This paper considers the use of transformative learning as a model as it facilitates transforming existing frames of reference through critical reflection of assumptions, validating contested beliefs through discourse, acting on one's own reflective insights, and critically assessing both context and application. This paper also draws on an educational intervention in Design at Technical University Dublin to consider approaches and methods that can enable transformative learning in a transdisciplinary setting.

Keywords: Transformative learning, trans-disciplinarity, sustainability, education policy

1 INTRODUCTION
We need to find better ways of constructing and exploiting the knowledge capacity of our HEIs. The challenge is to find effective means of crossing discipline boundaries to better exploit existing discipline knowledge with an aspiration to generate an increase in transdisciplinary activity and generate new and appropriate knowledge to address the challenges of the future. Human imagination, creativity, and innovation have failed to find adequate solutions to questions of sustainability within the existing paradigm. They have been shackled by the limitations of thought by which siloed knowledge has been constrained. The potential of the collective human imagination, creativity, and innovation is vast and capable of enabling us to cohabitate sustainably with all life on our planet. Design practice and design education are potential catalysts to address many of the global climate critical issues facing us.
The frame of reference which contextualizes this paper is informed by the term 'Anthropocene'. The 'Anthropocene' is increasingly accepted as a post-Holocene epoch and is becoming a keyword in debates about contemporary environmental challenges [1]. The Anthropocene Epoch describes the most recent period in Earth's history when human activity is a powerful geological force in its own right [2] and has begun to have a significant impact on the planet's climate and ecosystems. There is increasing evidence that humans are responsible for a range of impacts on many essential planetary system parameters and that many planetary thresholds have already been crossed [3]. However, somewhere between the rhetoric and divergent positions on the Anthropocene lies the potential to evolve. The issues and challenges posed through the debate on the Anthropocene may well reframe our relationship with the rest of nature, presenting a new view of our responsibility [4] as well as stimulating our imagination to generate new solutions and actions [5]. It is from within this space of potential and possibility that we need to harness our imaginative and innovative capacities to shape a means of cohabitation with the

forces of the planet. To understand the current debates, it is crucial to distinguish between the Anthropocene in a narrow disciplinary sense, as a geological concept, and the Anthropocene as a socio-cultural concept in a wider and perhaps transdisciplinary sense. That socio-cultural concept is where the focus of discussion in this paper resides. We need to assist the forces of nature to find an equilibrium based on a partnership where co-habitation is not centred on the arrogance of human dominance [6]. It is essential that we come to terms with our interdependence on the planetary systems. However, while many will claim an intellectual comprehension of this context, there is a poor transition to action.

2 FROM DISCIPLINARITY TO TRANSDISCIPLINARITY

In 2014, the US National Research Council outlined the importance of convergence between disciplines as a means to addressing complex global problems arguing that real-world problems do not respect disciplinary boundaries [7]. A strong narrative emerges from the literature around the need to shift from a tradition of disciplinarity to one of increased trans-disciplinarity within both the teaching and research spaces. Gibbons argues for trans-disciplinarity as a mode of educational application for future problem-solving and elaborates on the qualitative difference it provides over disciplinarity [8]. Crossing discipline boundaries can provide knowledge flexibility to engage more comprehensively with the educational, societal, and environmental challenges with which we are increasingly faced [9]. However, we must also recognise that the knowledge that resides within disciplines does provide the foundation for complex problem-solving. Understandably, with a lack of leadership or policy in shaping the nature of new knowledge construction and management, defence of the existing realm is justified. We need a multi-dimensional approach to teaching and learning that addresses the existing limitations and enables action and strategies to construct new models of knowledge construction, dissemination, and application. McGregor suggests we need complex transdisciplinary knowledge that can be used to solve the pressing problems of humanity [10]. While there are many educational interventions in both research and teaching which bring different backgrounds and perspectives, we need to enable better solutions and a big-picture view of the problems at hand [11]. We need to transition from isolated interventions to strategic actions and become part of a more effective and integrated global Higher Education policy. Higher Education is recognised for its central role in the construction and dissemination of knowledge, traditionally through discipline-defined silos. However, this model of disciplinarity is dissolving as an appropriate means of taking on the challenges and complexity of sustainability. Sustainability is singularly the most prevailing and pervasive contemporary question facing HEIs now and into the near future. We need to find more effective ways to exploit the knowledge capacity of existing disciplines in multi- and inter-disciplinary ways with the aspiration to generate an increase in transdisciplinary activity to stimulate new and appropriate knowledge, behavior, culture, and practice to address the challenges of the future. Attempts are being made, but progress is slow, we need to act more strategically and implement policies that enable and encourage transdisciplinary innovation to occur.

3 TRANSFORMATIVE LEARNING THEORY – A PARADIGM SHIFT

The challenges we face in the Anthropocene require a paradigm shift in terms of existing frames of reference. To enable such a paradigm shift, we need to challenge our individual and collective views on how we relate to the world around us. Our prevailing knowledge and experience construct the traditional frames of reference by which we are individually and collectively conditioned. These frames of reference represent how we make meaning from our experience of life and are influenced by many factors including culture, beliefs, authority, etc., which we often accept and assimilate without questioning [12]. Mezirow refers to these frames of reference as habits of mind which are 'broad, abstract, orientating, habitual ways of thinking, feeling, and acting influenced by assumptions that constitute a set of codes' [13]. Without overstating the obvious, it would appear these frames have been unsuccessful in managing our impact on the biosphere. We have failed to recognise our need to co-exist in a collaborative rather than predatory manner with all elements of our bio and non-biosystem. Our disciplinary frames of reference have provided us with extraordinary success within a dominant, narrow, and exploitative context where short-term success has prevailed at an incalculable non-economic cost. In a time of unparalleled global challenges which seriously threaten the Biospheres' capacity to sustain our existence, society must pursue equally unparalleled future strategies which fundamentally require a reconsideration of established mindsets to design and follow more sustainable pathways [14].

Mezirow developed his theory on transformative learning drawing on the work of both Habermas and Dewey [15]. Transformative Learning Theory (TLT) represents a way to reposition the frame of reference. This paper takes the position that a shift from disciplinarity to trans-disciplinarity is an essential shift in changing or transforming existing frames of reference. TLT presents the opportunity to not only change what we know or are able to do, but also to facilitate a shift in how we come to know and how we understand ourselves in relation to other humans and the natural world [16]. Transformative learning is defined as the process by which we transform conditioned frames of reference to make them more inclusive, discerning, open, reflective, and emotionally able to change [17]. The process of transformational learning facilitates changes in an individual's worldview, epistemology, self, ontology, behavior, and capacity which are evidenced in knowledge breadth and depth [18]. The process of transformative learning involves transforming existing frames of reference through critical reflection of assumptions, validating contested beliefs through discourse, acting on one's own reflective insights, and critically assessing both context and application.

4 HEI POLICY AND SUSTAINABILITY

Over recent decades, the Higher Education systems of many countries have substantially expanded to accommodate increased demand. It has become clear that HEIs are confronted with growing challenges in the face of globalisation, internationalization, and massification. Globalisation and the development of knowledge-based economies have affected changes in the character and functions of education throughout the world [19]. To remain relevant, HEIs require new kinds of strategic thinking and acting with regard to this international dimension [20]. Future-proofing HEIs requires us to be willing to do new things and to think outside the box. Differences between economic and social imperatives challenge the moral and ethical integrity and relevance of HEIs in the 21st century [21]. A lack of coordinated policy inhibits maximizing the potential of these institutions and generally involves a multiplicity of actors, with different agendas, often resulting in fragmented actions. In Ireland, for example, policy is informed by the Department of Education and the Higher Education Authority, which are in turn informed by the European Commission, the OECD, and UNESCO to varying degrees. However, in addition to the changing landscape which challenges the sustainability of the university in its current form, we are also faced with the challenges to human sustainability and the destruction of the biosphere. Sustainable Development Goals (SDGs) and Shared Socio-economic Pathways (SSPs), illuminate the challenges. We need coordinated policy to enable appropriate action.

Sustainability is singularly the most prevailing and pervasive contemporary question facing HEIs now and into the near future. For HEIs, this involves addressing questions around 'sustainability of education' and 'education for sustainability'. While 'sustainability of education' and 'education for sustainability' may appear to be different strategy and policy issues, this paper positions them as dynamically interlinked. We need to educate for a sustainable future in which our HEIs are relevant and consequently sustainable [22]. To future-proof our HEIs we need to look at how we do what we do. [23]. UNESCOs *2009 Trends in Global Higher Education* reminds us that "the role of higher education as a public good continues to be fundamentally important and must be supported" [24]. The importance of education as a means to meet the challenges of the future is acknowledged broadly. Evans argues that "*We urgently need education that confronts the challenges of our time*" [25]. Findler et al., argue that HEIs are "transformative societal agents that can contribute decisively to the development of sustainable societies" [26], acknowledging that a variety of global initiatives, already recognize the important role HEIs can play in this transformation. UNESCO emphasises this role arguing that "education is the most effective means that society possesses for confronting the challenges of the future" [27].

In terms of maintaining relevance, there is a strong imperative for HEIs to develop a strategic or policy position on the manner in which they address the management of new knowledge construction as well as its dissemination and application, both in teaching and research. Such action could assist in future-proofing the position of HEIs as the primary catalyst in addressing the increasingly demanding and complex problems of a stressed planet. HEIs may need to consider developing a relevant framework for coordinating and creating new disciplinary, interdisciplinary, and transdisciplinary approaches to inform teaching. [28]. An opportunity exists for Higher Education policy to recognize the value and power of the transdisciplinary potential of the collective knowledge resources at our disposal and enable a more structured and less ad-hoc development and exploitation of this potential. Cortese argues that the issues facing us now and into the future cross over disciplinary boundaries, "*Designing a sustainable human future requires a paradigm shift towards a systemic perspective emphasizing collaboration and cooperation*" [29]. However, its increasingly evident that institutional and higher education policy barriers as well as external environmental challenges are not being met with appropriate urgency.

5 EDUCATIONAL INTERVENTION – CASE OUTLINE

Through transdisciplinary engagement, Design has the potential to be a catalyst for taking on the challenges of a disruptive age. This paper draws on observations from a BSc Product Design run at Technical University Dublin. This program is a collaboration between three separate Schools, located within three different Faculties at the University. From its inception, a key objective was to provide students with the opportunity to engage with Business, Engineering, and Design and to immerse them in the culture of these different disciplinary areas. While there have been challenges involved in working across discipline 'tribes', the program has successfully negotiated these challenges and continues to move towards being transdisciplinary in philosophy and practice. It should be noted that the reference to this educational intervention is a demonstration of practice action in pursuit of transformative identity construction. Its effectiveness and impact are the subject of current research and will be reported on in future conference proceedings.

An example of a transdisciplinary/transformative approach is focused on a fourth-year Professional Practice module that uses a flipped classroom format to enable transformative learning. There is a comprehensive literature outlining the benefits of the flipped classroom approach in facilitating both experiential learning and the active construction of knowledge for participating students [30]. The students can build on their understanding of concepts through negotiation and discussion with other members of the class, including the tutor, and learn in a collaborative and socially constructed manner. Deep learning and the construction of knowledge are facilitated when individuals have the opportunity to actively engage with the subject matter as well as with other individuals [31]. This module aims to encourage and enable critical thinking and deep learning, both of which are essential elements of Transformative Learning Theory [32]. An important feature of the flipped classroom concept is pre-class preparation. Reading or video materials are sent ahead of the class. The extent of the materials for review is carefully curated in terms of both quality and quantity to ensure that the students are not overwhelmed by the materials and feel comfortable engaging with them. Over the course of the module, the students revisit and contextualize a variety of subjects and debate their interconnectedness. They debate issues of sustainability, ethics, design responsibility, intellectual property, entrepreneurship, contracts, and design management.

A café metaphor is used as a vehicle for the modules' physical and online presence. The transformation of the classroom into a café is both metaphoric and educationally responsive. While the café is still an artificial construct, it acts as a means to temporarily remove the students from the traditional classroom and simulate an altered reality that is conducive to rich discourse and debate. The 'cafe' session concept is metaphorically modelled on the cafe culture of the 19th century, where intellectuals, radicals, and artists could meet and debate. The café discussions or debates are loosely based on Problem-Based Learning (PBL). PBL is an instructional method in which students learn by solving problems and reflecting on their experiences [33]. PBL works because it encourages the activation of prior knowledge in the small group setting and provides opportunities for elaboration on that knowledge [34]. PBL, in the café sessions, centres around questions that are posed to the students as part of the café 'menu'. This requires them to address aspects of the materials which they have studied and discuss and negotiate an agreed solution or perspective in response to the questions asked. This provides a distinct form of active learning which is based on constructivist theories. The student plays the role of the constructor of information and takes an active role in the broader learning construction [35][36]. The nature of the 'café' classroom environment also allows the lecturer to interject in the different table discussions and contribute with appropriate practice anecdotes specific to the deliberations of the table. Anecdotes are particularly appropriate in a module on professional practice where there is limited real-world experience available to the students. Pringle & Smith encourage a shift towards using lived experiences and anecdotes as a foundation for teaching, arguing that this approach could support students to engage with the emotional, ethical, and spiritual aspects of the issues being discussed, rather than focusing solely on the intellectual aspects [37].

Each week students write a short reflective piece on their own learning in response to the materials they reviewed and the classroom discussions in the café session which captures their own learning journey. The rationale for engaging in reflection on learning is influenced by Dewey's [38] seminal work on reflection in education and the reflective practitioner. The act of reflection encourages deep learning approaches that are essential to enhance student knowledge [39]. Through both the discussions and the reflections the students are encouraged to question their existing frames of reference which culminates in them producing and presenting a personal 'Design Manifesto' to articulate their position.

Students are also encouraged to make recommendations on any aspect of the module that they feel could be improved, both at a micro and macro level. This provides students with a sense of ownership of the module. This element acts as a form of co-creation providing students with an opportunity to influence the content and structure of the module on an ongoing basis [40]. It also provides the lecturer with rich insights into the effectiveness of the teaching. Further research on this module is ongoing and will be presented at future conferences where the experience of the students will be captured.

6 CONCLUSIONS

This paper has outlined the prevailing contextual issues and provided an example of addressing them on the ground. Responsible innovation is an essential condition of a sustainable future. Design education is a potential catalyst to address many of the global issues facing the planet at this point in time. In pursuit of responsible innovation, we need to transform the current educational paradigms that have been shaped by traditional discipline definitions. This paper outlines the potential of Transformative Learning Theory as a catalyst for radically transforming the discipline order of higher education and re-orienting it into a more appropriate transdisciplinary innovation matrix. We need to cultivate transformation in the very way our institutions facilitate and enable the future of learning in an increasingly unstable natural ecosystem. If we want to transform teaching and learning, we need to transform policy. When policy is focused primarily on a research agenda and supported by funding streams with narrow agendas we will continue to fail to achieve our ambitious goals in terms of sustainability education. The challenges we face are substantial. We need a paradigm shift in education to take on these challenges. Design is a field with the means to enable transformative shifts in thinking and acting. That is its purpose from the first stone our ancestors shaped into a tool. We have the proven capacity to impact and shape our environment. What have we learned? Ignorance and irresponsible human-centric motivation in the shaping of our environment has brought us to the brink of being unsustainable.

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AN OPEN EDUCATION PLATFORM: LEARNING OUR WAY TO MIXING LIFE-LONG LEARNERS AND REGULAR STUDENTS

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ABSTRACT
In recent years we have developed an embryo of an open approach to education, where students, researchers and company liaisons take on a real challenge together, that the company partner needs to solve. These projects are part of the global Sugar Network on design thinking. Work conditions are realistic, and the initial brief contains a challenge, but no given solution to be developed, nor requirements to work towards. We have so far collaborated with varied organisations, including internationally well-known companies like Bosch, BASF, Tetra Pak and Barilla. We see great potential to further develop and scale this education embryo into a platform that will host a master's programme accepting a mix of newly graduated (bachelor) students and students with work experience who are there for a second stint of education. A master's programme would be designed for more long-term commitment to further education (1-2 years), where the project is the backbone of the education programme into which course content is added to support the process. Currently, as a prototype, we are running two Sugar Network projects in which employees from Saab participate in varied ways. Some Saab employees are in for the full eight months, some join only for the more theoretical book club, and some join separate workshops. In this way, we practice a learning by prototyping approach in line with what we teach. This paper presents both our thoughts on the overall master programme, as well as learnings from the past years and our more intense current set-up.

Keywords: Life-long learning, work integrated learning, professional education, prototyping

1 INTRODUCTION
Work Integrated Learning (WIL) has gained attention from universities worldwide as it has potential to elevate the employability of students [1]. Within professional fields, such as nursing, it is commonly used as a pedagogical approach to help students integrate theoretical and experiential knowledge [2], thereby putting into practice a view of learning as a knowledge acquisition process as well as a participation process [3, 4]. Previous research has explored various programme design and implementation models in WIL, including different delivery modes (e.g., internships, cooperative education, service learning) and examined their effectiveness in achieving learning outcomes. In this paper we will explore the development and implementation of an alternative form of WIL, where instead of university students going into practice, practitioners (in this case from Saab) come to university to participate in student project work, thereby creating a practice context for students within the university.
In 2010, for the first time in 30 years, Saab began designing it's a new jetfighter from scratch; the Gripen E. It turned out to be challenging in unexpected ways [5-6]. A jetfighter is the kind of product that can no longer be understood and developed in its entirety by any single engineer. It is a complex system, and one that is integrated into layers of further complexity, such as combat systems, national politics, and international relations. It relies on the collaboration between many different disciplines both within and outside of engineering, that are located both within and outside of the company. Over the course of 30 years, the complex system and its organization tend to start mirroring one another and provide a source of stability. The upgrading and development of an existing complex system is very different from the creation of a new one. After 30 years, not only technology has changed, but also methods, employee education and competences, as well as the way of organizing. When the system is a white sheet of paper the design freedom is vast. The difficulties encountered during this transition (such as living with

uncomfortably high degrees of uncertainty and ambiguity, working towards frustratingly fuzzy, sometimes contradictory, goals with undefined problems, and levels of complexity that can be paralyzing) opened up many informal discussions between representatives of Linköping University and Saab on how we educate engineers (and business students and others). The discussions resulted in an informal collaboration to re-think (further) education and to do so for both students who do not know the ways and employees who need to change their ways. In 2016, with financial support from Saab, we set up our first global design project within the SUGAR Network (a spin-off from Stanford's ME310) with a focus on teaching students Design Thinking in a challenge-based setting. This 15 ECTS challenge-based course has since grown into a 30 ECTS (8 month) programme and another three 7.5 ECTS courses (Design Thinking Basics, Strategic Foresight, and From Early Tech To Design Brief) for master's students have been added. Work conditions are realistic, and the initial brief contains a challenge, but no given solution to be developed, nor requirements to work towards. We have so far collaborated with varied organisations, including large, internationally well-known companies like Bosch, BASF, Tetra Pak and Barilla, but also organizations such as Digital Film Tree (USA), LHC Dam (Linköping women's ice hockey team), Montessori School Trilobiten (recently renamed Montessori Mondial) and Östgötasvamp, a local mushroom grower. Each kind of participant comes to the challenge with a different purpose, but they all work towards one common goal: to present an innovative proof-of-concept prototype solution to the challenge by the end of the project. For student participants, the project is part of a course in the final year of their studies and works as a transition towards working life. They get to collaborate with students of other disciplines and from other global universities and hone their virtual collaboration skills and create something real. They also get to collaborate, and co-create, with industry experts. For company liaisons, the project represents an opportunity to learn new methods, new ways of thinking, a chance of future-proofing development work by collaborating with students and researchers from around the world, but also a way to get new insights into what they are already developing. In this way, the set-up goes beyond involving companies in a client role, which has been discussed at E&PDE before [7, 8], even in light of the learning that companies can gain from this [9, 10]. It also goes beyond separate continuous professional development. The only other E&PDE publication we found that aligns with our approach is [11].

2 AN OPEN EDUCATION PLATFORM

In 2021 we started turning our course into a new kind of education programme that provides a Work Integrated Learning experience for students while also providing opportunity for life-long learning for practitioners. We referred to it as an Open Education Platform (OEP). On a Swedish national level, 'Teknikföretagen' had then declared that in order for the Swedish technical industries to survive the rapid transitions that are going on right now in areas such as AI and automation, we need new models for education where what students learn is more relevant for their later employment and where the possibility to re-learn, change direction and build competence throughout a professional life is better supported. The Swedish ministry of Education had then posted their action plan to make higher education more accessible and life-long learning more possible with financial support for individuals choosing to pursue education later in their careers. Up until then, most of our regular specialization courses that might be interesting for practitioners were tied to admission to full study programmes, which would tie up too much time for a practitioner to be feasible to attend. In our OEP the Regular Students take part in a 30 ECTS challenge-based course where missions drive both learning and projects. They work in interdisciplinary and internationally distributed teams to take their challenge from white paper to proof-of-concept solution. Teaching modules are delivered on a just-in-time basis. Workshops on for example user interviews and observation methods are hence given when students start doing user research in their projects. For Practitioners we offer the programme as a smorgasbord of bigger and smaller commitments ranging from shadowing the 8-month process to participating in a 3h workshop. There is also the role of Liaison for the companies that provide the challenges, where the practitioner meets with the student team on a regular basis for coaching but also follow-up on progress made. Some practitioners will also come to the programme to teach a unit as part of their competence development. This has been done in the form of a Master Class where the practitioner introduces for example a tool that the students then get to practice together with the practitioner. This is based on the principle that by teaching someone else you start thinking about what you actually do, how, and why, which can lead to insights for the practitioner-as-teacher as well.

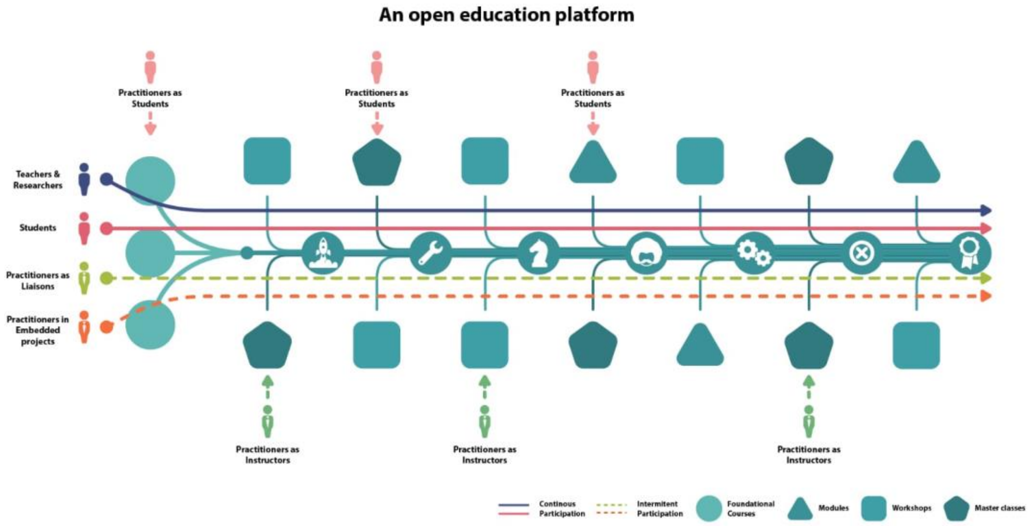

Figure 1. The model of an open education platform with multiple ways for industry partners to participate

3 THE FIRST COURSE PROTOTYPE 2022/2023

After the initial start with Saab in 2016, and after having worked with a score of other organizations, in the academic year 2022/2023 we picked up the collaboration with Saab again. Not by having Saab as the corporate sponsor, but by engaging experienced Saab employees in our Open Education Platform. The development of the platform is funded by Vinnova, with Saab putting their employees' time in as match funding. We have prototyped this open educational platform around two international student projects in teams of seven to eight, where half the team is located at another university. In total we had seven regular students in our Studio. In this first round we created four different participation modes for the seven Saab employees to see what would bring value. One person followed the programme as a theoretical exercise, taking part in book clubs (we read and discuss instead of giving lectures), one person did it as a practical exercise and took part in workshops only, two persons participated in book clubs and workshops, two persons did the full package as shadow members of our student teams. They also participate in some feedback sessions and made small contributions towards their team's project work.

3.1 Projects

Both our projects were with the same partner university and were funded through an EU initiative where researchers with early-stage technology are connected to courses and students whose role it is to find uses for the technology that has a positive impact on our world. We here set up a 'relay race' where Strategy Master students in a five-week course, using Christensen's Jobs-to-be-done framework [12], would identify markets, uses and users for the technology, and do initial user research, culminating in a design brief. This design brief was then further developed by the Teaching Team before it was handed over to the international project students in the form of a challenge. One project hence went from optical meta-surfaces as a technology to a "Digitalization of the Beehive" challenge for the eight-month project, done in collaboration with the local Beekeepers' Society and the technology owner. The regular student teams consisted, on each side, of three and four students respectively. Our local students had either engineering or business backgrounds whereas the international team as a whole also had design students.

3.2 Book club

In our education, we strive for a dual challenge. We challenge students to build prototypes and learn by doing (which is typical for Design Thinking), but we also challenge students to develop a theoretical understanding of what they do and a language that makes it possible to reason and discuss practice. Instead of lecturing we have chosen a weekly Book Club setup where we read foundational works and then meet up to discuss. The chosen literature covers three levels of abstraction where the lowest one mainly categorizes and 'talks about' different tools and how things are done (Storytelling, Journey Maps etc) in practice [12, 13, 14]. The next level of literature [15] adds theoretical connections and a common language that we can use to explain why we do things the way we do. It also connects to stories from practice. The final level of literature [16] aims to give our students concepts and underlying mechanisms also on a more abstract level (and therefore applicable in multiple contexts of practice) and helps us understand design and problem-solving and put contingencies around design methods taught so that students also can discuss and change methods as they face new types of situations. We read a chapter or two per week and meet for two-hour sessions. We start out discussing in small mixed groups first to together figure out what the author was trying to say and also how that relates to what we do in our projects. We then move on to a moderated full group discussion to share impressions and draw conclusions.

3.3 Workshops

Workshops are more hands-on oriented, half days or full days, with a mix of brief backgrounds and introductory mini lectures followed by practice, feedback and drawing out learnings. We start with a 24h simple design challenge where students get to experience a full, but quick and shallow, iteration of Design Thinking. Other workshops focus on topics like User Research Methods, Synthesis, Low Fidelity Prototyping Methods, or Tinkering Systems (Prototyping), timed and tuned towards the needs of the projects. The Low Fidelity Prototyping workshop for example included an exploration (by doing) of different media for idea representation, contrasting starting with clay versus starting with a collection of technical components (see Fig 2a&b). The Tinkering Systems workshop used (board)game design as a way to design and tweak systems in quick iteration (see Fig 2c&d).

Figure 2. The prototyping workshop included an exploration of different media for idea representation, contrasting starting with clay versus a collection of technical components (a & b) The tinkering systems workshop used (board)game design as a way to design and tweak systems in quick iteration (c & d)

4 EXPERIENCES

We are currently at the end of our prototype-year. So far, we have held several feedback sessions with the industry participants, as well as informal reflections, to see what works, and what needs to be improved. This feedback both covers the content of the platform as well as the formats in which it is delivered. Within the Saab organization there is a so-called champion. A manager strongly behind this set-up that both pushes employees to participate as well as pushes the business organisation to enable it. This manager is not necessarily the line-manager of all the employees participating. All actual line-managers of participants therefore all had to be okay with the initiative as well. Informal feedback from the Saab project partner indicates that both the book club and the separate workshops are actively being discussed when participants return to the workplace, creating a bit of a buzz. Employees feel triggered to reflect on how to translate insights from modules and workshops into their industrial practice and discuss those with colleagues who did not attend. Their engagement with new theory (at least to them) and knowledge brings inspiration. A practical example of this is their realization that prototyping could and should be much earlier in the development processes. “Currently, we usually spend only 10 second in the problem field, and years in the solution field. We build too high fidelity too late in the process for maximized learning. It would be better to stay in the problem field much longer.” (See also [14]). From the two employees who are involved most thoroughly, we hear that it is also interesting to follow the student projects. Not so much for their content, but to try to take a helicopter view, zooming out from their particular problems to more generic patterns. And then to understand those challenges in a more generic way and link them to the theory from the book club. It helps to fully comprehend the day-to-day development processes they are in in their industrial life. On a more practical, logistics level, aligning with the academic schedule goes well enough if schedules are available in time. Most challenging for industrial participants is to find the time to read the material for the book club (usually in the evenings). Book clubs are run within Saab as well, but those are paced adapted to working life. Our book club is adapted to student life, so the reading pace is much higher. Industrial participants of workshops feel out of their depth sometimes, missing the grounding in theory that the book club readers do have. Here, providing some summary material would be helpful. From a social cohesion point of view the mixing of students and professionals goes well. "I thought we would have experienced the difference of age much more than we actually have." From the student side, the participation of industry professionals has been a true enrichment, through the added professional experiences and reflections. From a teaching point of view, running a book club as well as workshops that are perceived as relevant by professionals from industry as well as by students requires more than ordinary teaching. As a teaching team you are not automatically the most knowledgeable about all aspects of the course. Being able to deal with the associated uncertainty does require a certain level of maturity and experience, to dare to let sessions go in which ever direction turns out to be most intriguing. One thing that helps here is to have people – both teaching team members and participants – who can tap into 'a library of weird stuff', a wide array of interesting examples from a range of fields in which they can spot and help others see relevant connections. During the book club, having people with industry experience participate helps provide examples from practice to both digest and reflect on the proposed notions. Having the industry perspective helps students see the relevance. At the same time, for the Saab employees it brings new ideas. The resulting mix of fresh ideas with a reality check makes the discussion sessions fruitful. One of the corporate participants in the book club is also pursuing a PhD degree, as an industrial PhD candidate (a Swedish phenomenon where employees in external organisations, such as industry of (semi)governmental organisations pursue a PhD anchored in their daily work, and within their regular contract hours). He will likely also credit the book club as a reading course as part of his doctoral education.

5 LEARNINGS AND WAY FORWARD

What our Open Education Platform does in essence is that it creates a practice context at the university that simulates the future workplaces of many of our engineering and business students in a rather realistic way. This means that a community of practice-like [17] participation learning opportunity is created. Learning from experience only can however be a slow process, and also one that does not always teach the right lessons [18]. In the delivery type of learning on the other hand, knowledge has been externalized and abstracted into lessons that can more easily and purposefully be communicated in books and lectures. Learning from Book Clubs here provided more efficient delivery type of learning. For an inexperienced person, such lessons may seem rather dry, but for a person whose head is already full of experience, such lessons can provide a way to make sense of that experience. This is also one of the synergy effects we can see in mixing experienced and not very experienced students, and one that was to be expected. The synergy effect we did not expect however, was the way the practitioners' intermittent participation in the students' project work would elevate the practitioners' learning process. They were in a way able to live the experience vicariously, thereby helping them see what something that had been described in words in their articles might look like in practice without having to spend full time in the practice. Seeing the students' failures and successes also helped practitioners to better understand what they can expect from newly graduated students and how they can put them to better use as well as better support them. The next step to further build on this will therefore be to have a Saab provided challenge, which would be closer to the practitioners' normal context and the kind of work in which they will implement their learnings.

The current version of our project course stands at 30 ECTS points over an eight-month period. We see great potential to further develop and scale this education embryo into a platform that will host a master's programme that accepts a mix of more newly graduated (bachelor) students and students with work experience who are there for a second stint of education. A master's programme would be designed for those ready for a more long-term commitment to further education (1-2 years), where the project is the backbone of the education programme into which course content is added to support the process. In evolving the current course into a master's programme of either 1 or 2 years, both the project itself might be scaled, as well as other courses, international exchanges and a thesis would be added. However, components of the programme, such as Foundational Content Courses (weeks), Workshops (days), and

Modules (hours) will be open for practitioners to participate together with students. In addition, there would also be the possibility for companies to have employees participate in the project as liaisons. This would support lifelong learning and create opportunities for more short-term education commitment and stronger integration between education content and company work assignments, as well as better prepare students-about-to-graduate for work life expectations. In conclusion, through this prototype of an open educational platform, we are learning our way towards mixing life-long learners and regular students in a way that is perceived as highly rewarding by the students, by the industrial participants and by the teaching team as well (which also aligns with the findings by Van Boeijen in a similar mix of practitioners with regular students [10]. Scaling small-scale initiatives to a fully fletched master's programme, will require buy-in from both additional industrial partners, as well as Linköping University. We are also in the process of securing the required funding for development from either external and/or internal sources.

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ANNOTATED FAILURE AS A DESIGN COURSE DELIVERABLE

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ABSTRACT
In a course on sustainable design strategies, students explore different notions of what it means to be sustainable and what that, in turn, implies for how one should design products. Many of the philosophical notions that have been proposed (such as Circular Economy, Cradle 2 Cradle, and Biomimicry), and the tools and methods that accompany them, still have substantial shortcomings. As a teacher, I could lecture about those shortcomings and talk about many cases, each with their own particular hurdles, but I deem it more educational for students to bump into, or trip over such hurdles themselves. Enter the notion of Annotated Failure. I ask students to try a sustainable design method until they get stuck, and to submit an annotated version of their design process as a course deliverable. If they reflect deeply on why they got stuck, they will see that often the design method failed them. Still, students often feel *they* failed themselves, even after finishing the course. In a certain sense, this may mean I have failed to adequately implement Annotated Failure as a teaching strategy. This paper serves therefore as an annotated reflection.

Keywords: Failure, tools and methods, sustainable design, annotation, reflection

1 INTRODUCTION
I, myself, was educated at Delft University of Technology in the Applied EcoDesign school of thought, which strongly dominated in the 1990s. It mainly focussed on the technical side of product design, aiming to select better materials, reduce energy consumption, improve durability [1]. The aim often was to find true win-win situations for industry, where environmental improvements also made economic sense. Streamlined LCAs would inform our design process and help validate our designs. We also worked on developing environmental benchmarking processes for companies, in order to anchor EcoDesign into business processes [2]. A lot of progress was made, yet all these tools and methods also had their clear limitations. They for instance have a tendency to favour incremental improvements only. Hence, globally, alternative views and ideas started to emerge, such as Cradle-to-Cradle, biomimicry, design for sustainable behavior, and Circular Economy, to name a few.
Years later, about a decade ago, I attended a presentation on Cradle-to-Cradle at the Dutch Design Week in Eindhoven. The speaker, an architect, talked at length about material flows in buildings. At a certain point, he pulled out his cell phone and asked why we did not design such objects based on the same Cradle-to-Cradle principles. Anyone with an inkling about the design of cell phones would be able to point quite some reasons why not. Instead, the audience enthusiastically nodded their heads in agreement.
This anecdote illustrates a tendency that is rather common in design for sustainability. The philosophical perspective about how the world ought to be organized sounds beautiful and convincing. A few examples where it seems to have worked strengthen the sales pitch. That those examples are precisely the ones where a philosophy makes most sense is lost on the novice design reader. Hence, when teaching on the full range of sustainable design approaches, one needs to go beyond the basic texts, such as [3] for Cradle-to-Cradle, or [4] for biomimicry.

The thinking behind the course described in this paper was further developed by supervising an early MSc thesis on Circular Economy by Florian Mesch [5]). He worked on public lighting products that would have a 15-year lifespan. He found numerous challenges with this, such available bank loans not extending beyond 8 years, not knowing future recycling infrastructure that far ahead, let alone not even knowing whether the company, at which he did his thesis work, would even still exist at the end of the initial lifespan of his design light fixture. All three questions aren't obviously clear when you start to explore a sustainable design strategy by reading a book or watching a TED talk. And many such books and TED talks have appeared, articulating beautiful notions of how the world should be organised and how design and innovation might help bring such a preferred future about. But there is a clear educational need to move beyond them.

2 A SIDE NOTE: FAILURE IN DESIGN EDUCATION

A second observation on design education on which this paper is based, is that the way design education is set up does not always mimic reality so well. The success rate of design projects in practice is rather low. Yet in an educational setting with design projects, we let all student teams continue to the final presentation (for obvious reasons), even if a stage-gate model is followed. As if no innovation projects are ever terminated for lack of results. Also, to keep things interesting for both students and coaches, we often deliberately choose to take project into novel and therefore high-risk directions. Even if several teams are working from the same brief (not realistic in practice, but common in design education), all teams end up presenting their final result as if it was a good result that should go into production. It would perhaps be better if during final feedback a more realistic reflection would be given as to which projects would have been terminated at which stage gates. As long as the students themselves correctly assess that a design is a (partial) failure there need not be a correlation with their grade. Exploring a design direction that seems promising to arrive at 'no' as an answer can both be an excellent result (with a high grade) and an excellent learning experience.

3 COURSE SET-UP

The course on Sustainable Strategies described here, is a first semester course in our international master's programme in Design. This two-year MSc programme takes in a wide range of students who either have an undergraduate degree in some field of design (e.g., product design, graphics, cabinetmaking, interaction design), or another undergraduate degree with a separate track record in design (we have for instance had students from psychology and electrical engineering). Within the master's programme, students can select a track focused on sustainability, in which case the Sustainability Strategies course is their first track course. Hence, the aim is both to familiarize the students with existing philosophies, methods and tools for sustainable design, but also to let them experience the limitations and shortcomings of these approaches. The learning objectives in the syllabus are therefore as follows: "The main objective is for students to develop knowledge about, and skills for different perspectives on sustainability and associated design strategies. After the completed course the student shall be able to:

- Articulate the differences between visions on sustainability and their associated design strategies,
- Argue for the selection of a specific strategy in light of a given challenge, while articulating its limitations,
- Independently apply one of the strategies to a design challenge.

Over the course of 10 weeks, we start with jointly reading some basic texts in the first few weeks, to align the knowledge level of the varied group of students. We start with two papers that present an overview of different perspectives on sustainable design [6-7], followed by De Pauw's empirical comparison based on student teamwork [8], part of a basic text on Circular Economy [9] and finally, because the ones above are mostly on environmental sustainability, a text on design justice as part of the social side of sustainability [the introduction of 10]. In two sessions we discuss the reading material seminar style, after which students select their own focus. After several years, I see Biomimicry and Design Justice as two very popular focal points in our programme. Students continue reading individually for a couple of weeks, to familiarise themselves with the philosophical notion of their chosen strategy, and the methods and tools that have been developed for them. If they choose biomimicry, they might read more of De Pauw's work [e.g., 11-12] and if they choose design justice, they might read Perez book on invisible women [13] or Kristof Vaes' work on stigmas surrounding prosthetics [14]. This focussed reading material is selected with the help of the instructor. We continue to have joint seminar-style sessions in which we discuss the reading, so that all students hear about each other's chosen focus strategies.

Subsequently, they try out their focal sustainable strategy on a very small design project (on which they spent roughly 8 working days). But here is the thing: they are not asked to deliver a finished design. Instead, they are required to submit an annotated design process up to the point where they got stuck. So, the deliverable is not the usual finished design, but rather an Annotated Failure. Students find this very challenging ("*You know I'm gonna ask you five more times, right?*"), because they feel it means that they themselves have failed, instead of the sustainable strategy, method or tool they employed, which is actually coming up short.

The notion of Annotated Failure as the course deliverable was to some extent a consequence of allotting sufficient time for reading in the beginning of the course, and the limitation of having only 6 ECTS credit points. Reading previous research consists of about a 100 pages per week for the first weeks. This reading yields much deeper insight than if I were to select a single design for sustainability manual as course literature. However, in hindsight, I feel the notion of annotated failure turned out as a valuable educational model. There are of course links to the notion of productive failure [15], but it is different in the sense that it is the final deliverable and not a step towards finding a final design.

4 STUDENT EXPERIENCES

By trying to execute a cradle-to-cradle project, or a biomimicry project, or a design justice project, and getting stuck because of information that is unobtainable for a student, undoable within a timespan of the course, or because decisions need to be based on the unknown availability of recycling technology in 2035, they gain much deeper insights into what such strategies both can and cannot do. Of course, many of the projects bump into limitations related to the limited time and the limitations of the pre-existing skills of students either regarding sustainability skills or regarding the primary functionality of their product. For instance, regarding acoustic modelling for a sound booth made of renewable materials. The skills of the students are a limitation, but *also* the available data for such relatively new materials compared to more traditional engineering materials.

Another student, working on material wear and aging as a topic, wrote "*The explanations are easy to understand and it is possible to visualize what the authors mean by them. However, it was difficult to actually implement these in my own design proposal. There are certainly materials that can fit the project better, or that age in a more graceful way, but the difficulty lay in implementing more than just one of the proposed strategies in the same project. Another difficulty is knowing whether your proposal actually meets these criteria. What is really unique and how do you celebrate imperfections?"*

Examples of limitations of the tools and methods students uncover, are for instance the data needed about materials in Cradle to Cradle, especially regarding potentially present trace molecules. (This of course combined with having some base chemical knowledge and skills which students might not have). Many companies will be reluctant to release their proprietary production info. For large, and rich, companies there are ways to deal with this, but for students or independent designers it may present insurmountable hurdles.

In Biomimicry, we search for inspiration in nature. There is debate about terminology, but here we take biomimicry as generating solutions that are sustainable on a system level, not just technical inspiration which might be captured by the term biomimetics. In the seminal book by Janine Benyus [2] there are many examples, but they all originate with biologists realising that nature has a wonderful solution, that might solve problems in real life. Starting with a given problem is a whole different game. "Ask a biologist" is the advice, yes, but which one? Is nature's solution to your problem located in an insect from the amazon, or a plant in the alps? or both? The work done in Delft in the Nature Inspired Design project[12] helps, but problem-driven biomimicry projects remain challenging.

Due to time limitations within the course, actually demonstrating through some proper validation, that your idea works is often also beyond the scope of the course. An example here is the work by a student, Petter Alsén, working on the aerodynamics of a hydrodynamic power generator by applying irregular shapes inspired by a Humpback whale's tubercles (the irregular bumps on their flippers) [16-17], see Figure 1. Even though a computer simulation or prototype test is beyond the scope of the course (and in this case also beyond the skill set of the student), it is possible to clarify how such a validation could be done. Hence, by asking for an annotated design process up to the point they get stuck, students (hopefully) feel more empowered to actually say that beyond the point where they ended up, they simply do not know. Instead of the usual claim of self-confidence in their unvalidated design.

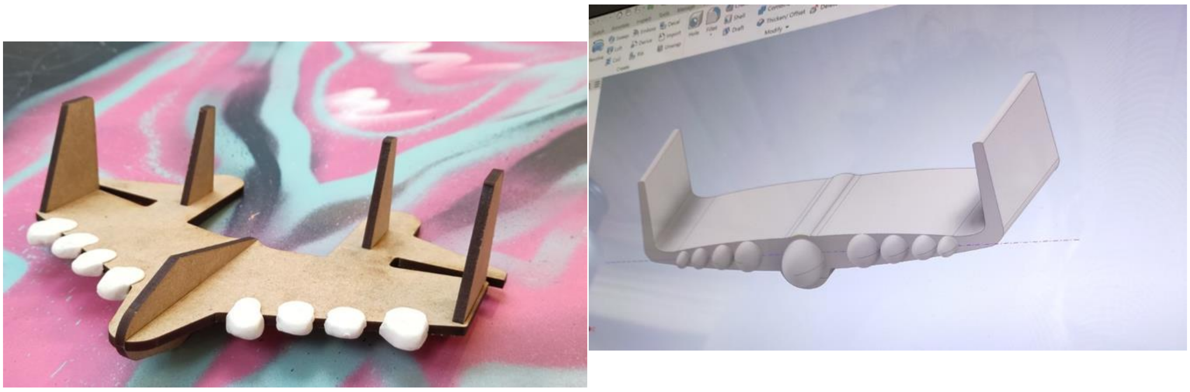

Figure 1. Models of the hydrodynamic power generator with tubercles. (credit Petter Alsén)

5 CONTRASTING ANNOTATED FAILURE AND PRODUCTIVE FAILURE

As said, there are some similarities between Annotated Failure and Productive Failure [15,18]. They are however distinctly different:

Productive Failure lets students explore a problem in an *unguided* way first, relying on their pre-existing knowledge and skills. By analysing the resulting sub-optimal and incorrect solutions found, a deeper understanding of the current limitations of the *students'* abilities are made explicit, creating a need-to-know for tools and methods that can help them find the optimal solutions.

In Annotated Failure, students familiarize themselves with a sustainable design philosophy with its associated methods and tools, and then try to apply those in a *guided* way, until they get stuck. The reason they get stuck may partially rest upon limitations in their skills and knowledge but is predominantly a limitation of the *tool or method* used.

6 FEEDBACKS TO STUDENTS

The cohorts taking this course have been very small, with the largest groups being 8 and 9 students respectively. This allows for more direct contact between teacher and students, and a form of continuous formative feedback. (Which includes repeatedly articulating that getting stuck means the method or tool is failing them in the contacts of their project; they are not failing themselves). In the more summative feedback at the end, I re-iterate the learning objectives of the course, and reflect how the student developed themselves in light of those. This is done in an individual message, which should look like this, slightly edited, actual example:

"By choosing what, in essence, is a very simple product, you were able to dive into three sustainable strategies instead of just one. Reading through your reflections of the different philosophies and as well as tools, I see a repetitive theme: The theory is beautiful, but practice is unruly. How does a strategy deal with making compromises in practice?

I feel you really experiences (and can now articulate) the strengths and weaknesses of C2C and biomimicry. On the EcoDesign side you took one specific version of EcoDesign (not the most common definition) but that is fine.

Based on your documentation, I'm entirely confident that, given a specific product design challenge,

- *You could now select which sustainable design strategy to apply (and explain why),*
- *You would know to some extent how to execute it and would know for which aspects you would need to dig deeper.*

As a close of the course, it may be nice to look at the graph of Ceschin and Gaziulusoy, to reflect on which part of the field you now explored. (and whether you agree with where they placed your strategies)"

Formal grading happens on a fail/3/4/5 scale, with 3 being sufficient, 4 being good and 5 being excellent. Because this is a scale with rather wide steps, there is usually limited focus on reaching a higher grade. (The feedback example above represented a solid 4).

7 REFLECTIONS FROM STUDENTS

At the end of the course, in informal feedback, student express an ongoing unease with the unfinished nature of their projects. It is so different from what they are used to in the course deliverables during their undergraduate programmes, that they struggle to distinguish between the tools and methods failing them, or they themselves falling short.

It is obvious though, that student do honestly discuss the limitations of their project. It seems the course does provide the context in which they are confident enough to do so.

Several students have returned to the topic and/or method of this initial course when it became time to select their thesis project a year later, in some cases truly picking up where they were forced to leave it at the end of the course. As one student wrote: *"Unfortunately, I did not get as far in my design process as I had hoped. Time was short and I got stuck a few times on the way. I would therefore like to take inspiration from this project and further develop it in another course."*

8 FINAL REFLECTIONS

Many of the methods and tools available for the different approaches to design and sustainability have serious limitations. The same would apply to other relatively new design fields. When teaching those approaches, it is important to make students aware of those limitations and have them realize that they may cause failure in a design project. Such failure is not necessarily their fault, or a limitation of their skills and knowledge.

Asking students to submit an Annotated Failure as their final deliverable of a design course helps them to develop a more mature stance in relation to failure, detaching the quality of the process (and the quality of the learning) from the quality of the result. It also helps them develop a more realistic picture of what a particular sustainable design strategy can and cannot do.

The course has run for 6 years now, with a total of 27 students. Which means there is quite some experience, but numbers are too low for now to attempt any kind of quantitative analysis. Also, the small badge size allows for personal coaching and feedback which may make this educational set-up hard to scale to larger cohorts. The students have explored a wide range of directions from stigma-free wheelchairs and gender-neutral toilet signage on the social side of sustainability, to behavior change projects around thermal comfort in households of migrant families, to biomimicry in hydropower generation. Some students came closer to a finished design than others. All still found the notion of handing in an Annotated Failure challenging. Nevertheless, several students have come back to their attempt in this first semester course once it was time to articulate their thesis project. So, it does seem to have made an impression on them.

ACKNOWLEDGEMENTS

The idea behind Annotated Failure as an educational concept has developed over many years, and thanks to the inspirational work of many of the students with whom I had the privilege of working. I want to thank them all.

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DATA VISUALISATION AS A TOOL FOR PUBLIC ENGAGEMENT AND EMPATHY BUILDING

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ABSTRACT
Visualisations provide an accessible way to unveil new patterns or promote new perspectives on data. Data visualisations can also aid in highlighting the context and scope of social issues and is a compelling way to disseminate research findings to the general public. This paper presents an interactive exhibit displayed at the 2022 Accelerate Creativity and Innovation Festival, at the Smithsonian Institution's National Museum of American History. The exhibit utilised participatory and interactive visualisations, prompting visitors to share their experiences regarding trust and respect in maternity care. This case study showcases the potential impact of utilising participatory visualisation activities by a design research team to inform and actively involve museum visitors in exploring sensitive topics surrounding maternity care and postnatal care inequities. The use of these activities allowed for an inclusive experience, encouraging visitors to actively participate, reflect, and contribute to the conversation. Additionally, it allowed the team to disseminate and validate their findings.

Keywords: Participatory data visualisation, human centred design, design research, maternity care disparities

1 INTRODUCTION
In the field of public health, data visualisations are critical tools that aid in identifying disparities and implementation gaps, and support strategies for reaching population groups that are most in need of interventions [1]. Similarly, data visualisations in health care can assist in identifying patients based on their treatments and care needs. Data visualisations can offer health professionals the chance to recognise patterns of racial and ethnic inequalities, as well as the effects of structural racism, although their application in this context has been underutilised [2]. These types of visualisations rely on large data sets, visualisation software, and computing power. They are designed to find and illuminate truths. In design, data visualisations are often used for summarising and analysing data from research to make decisions about the design direction or to communicate insights to stakeholders in a clear and compelling way. Data visualisations can also be used by designers and artists to promote empathy by connecting stakeholders to the human experience. In this context, the intent is often to engage with the viewer's emotions, by eliciting responses and connecting viewers to the data on a deeper level [3]. The goal of these types of visualisations is not always objectivity. Their interpretations often incorporate personal experiences, individual perspectives, and the context of the viewer's experience [3,4].

Data visualisation may also be participatory, incorporating activities where people contribute data and actively partake in the generation of the data visualisation [4]. By encouraging individuals to contribute their own data to a shared visualisation, these activities create a sense of ownership and engagement for participants. These activities can be powerful tools for generating public awareness and promoting social discourse [5]. As a result, there may be unexpected uses, thought-provoking discussions on data, and unconventional dissemination of findings on data-related topics that hold significance for society.

In health care, participatory data visualisations can be particularly effective in promoting shared understanding among stakeholders, for instance between patients and health care providers. The contrasting perspectives of care experienced by patients and families across race and ethnic identities are not always evident to health care providers and administrators. This paper describes the use of visualisation tools around disparities in maternal care in the context of a museum exhibit. The intention of the activity was to engage the general public and students in discussing a sensitive topic and shedding light on inequities.

2 EXHIBIT DEVELOPMENT

Currently, the United States has significant differences in the incidence of adverse health outcomes related to pregnancy and childbirth based on race and ethnicity. This includes mortality rates due to pregnancy or delivery complications, as well as rates of negative health consequences resulting from unexpected pregnancy or childbirth outcome [6].

The authors of this paper are a team of designers working with health care experts at University of North Carolina at Chapel Hill and The Ohio State University on an Agency for Healthcare and Research Quality (AHRQ) funded grant to improve systems of perinatal care. The team is taking a human-centred approach to developing interventions by centring the needs of birthing parents. Birthing parents are included throughout the design process to create solutions that meet their needs and preferences. The research methods used in this project included shadowing, naturalistic video recording, interviews, focus groups and workshops.

The design team's project was selected to represent North Carolina State University at the 2022 Accelerate Creativity and Innovation Festival at the Smithsonian Institution in Washington DC. This festival was hosted at the National Museum of American History. During the three-day event, fifteen universities showcased thirty-eight interactive installations themed around place and environment; health, body and mind; and culture and the arts. The design team was tasked with creating an interactive display or exhibit that would allow the sharing of the project to the general public, including families, children, and students. This venue provided an opportunity to disseminate and validate research findings, share the human-centred design approach, and collect data. The team's goals for the exhibit were twofold: 1. to educate visitors about existing disparities in maternity care and research findings 2. engage visitors in sharing and collecting data about disparities regarding their postnatal experiences. In order to provide an overview of the project in maternity care to the general public, the team developed three tools to meet the first goal of educating visitors to the museum exhibit. First, the team wanted to provide an overview of the project and research methodologies along with some of the most impactful and relevant findings. To do this, the team designed a looping slideshow, presented on a large format video screen so visitors understand the context of the research quickly. The slides portrayed large scale artwork portraying birthing parents and direct quotes from birthing parents that share their feelings surrounding their experiences in maternity care (see Figure 1).

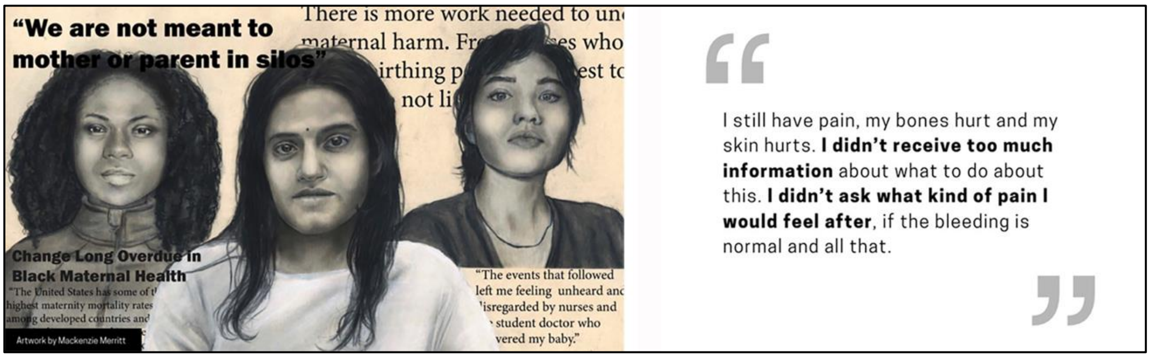


Figure 1. Slide show content

The second tool utilised quantitative data from maternal mortality and morbidity statistics reported from the Centres for Disease Control and Prevention (CDC) [7]. This data was presented as an interactive display, using Figma, on a touchscreen computer. The touchscreen display enabled specific interactions to address frequently asked questions around disparities in maternity care and communicate information in an interactive way. This was a user-driven experience, where visitors could explore questions and the associated answers at their own pace. The intent of this tool was to convey the magnitude of the problem in an accessible way.

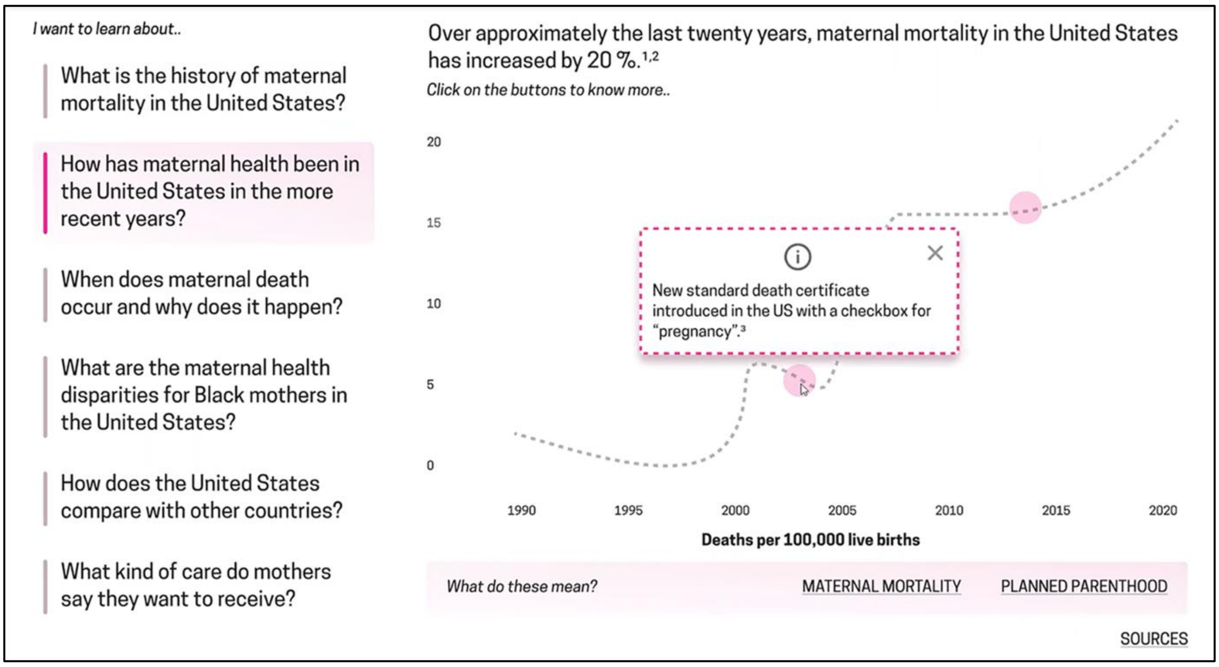


Figure 2. Interactive display

The third tool developed to educate and inform visitors was an animated video display that shared lived experiences of birthing parents and their families in the postnatal unit. Through these animations, the visitors would be able to hear and see examples of interactions between patients and health care team members, learn about those experiences and, in some cases, verify their own experiences. The goal with this portion of the exhibit was to use digital stories as a provocative artifact for discussion, inviting people to view, question, and reflect on the inequities of postpartum care [8].

Figure 3. Screenshot of animated video display

2.1 Engaging participants in sharing

To accomplish the second goal of engaging participants and collecting data about disparities in postnatal experiences, the designers developed a participatory data visualisation display which allowed visitors to share their experiences in an unidentifiable way. The objective was to let visitors respond to questions about disparities silently or through dialogue with the design researchers. The board was intended to be the active component of the exhibit. It had to be user-friendly, straightforward, and easy to comprehend. It was important for the activity to be observable to individuals passing by and appealing to them. The visualisation board was meant to attract people into the exhibit and encourage them to interact with the animated videos and the interactive data display. The design team aimed to make the board tangible and physical to distinguish it from other technology-driven projects at the festival.

In searching references, one of the design researchers experienced an *East Meets West* Data Strings exhibit by Domestic Data Streamers in Hong Kong's Business of Design Week 2015 that reflected the qualities described. *East Meets West* was a tangible exhibit that transformed as participants provided responses, revealing communal trends around living and working based on where participants are from. Participants were prompted to respond to various questions by weaving their answers into the installation, creating a display of shared beliefs and statistics that allows them to juxtapose their responses with a wider context [9].
The design researchers wanted the exhibit to incorporate the ease of use and accessible qualities of the data string board in addition to allowing the participants to verbally share personal stories in relation to their answers. The design research team wanted to afford participants the ability to share as much or as little as they wanted while allowing them to see other participants' answers to the survey.

Figure 4. Participatory board questions to engage visitors

The questions selected for the survey on the board were based on research conducted by the authors on a related project in maternity care. These questions addressed issues about informational needs and emotional needs during the postnatal stay [10].

3 RESULTS

The exhibit was open to the public for three days from Friday, April 8 – Sunday, April 10, 2022, 10am to 5:30pm. During this time, two industrial design faculty and four research assistants staffed the exhibit in pairs during four-hour shifts. The museum reported approximately 11,000 visitors to the museum each day. The design research team conducted a group debriefing session at the conclusion of each day to record notes on the responses from exhibit participants.

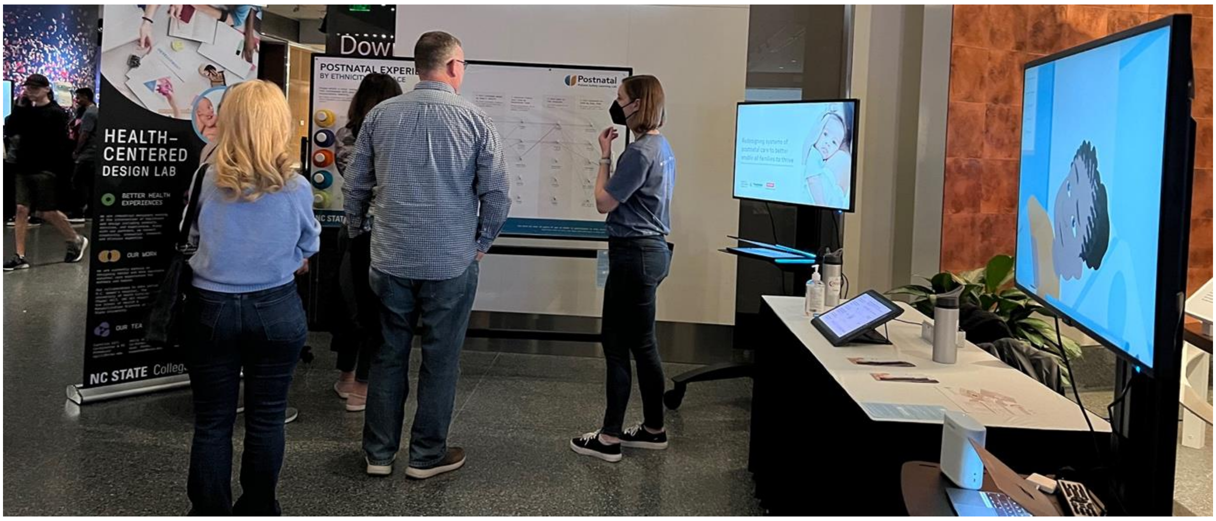
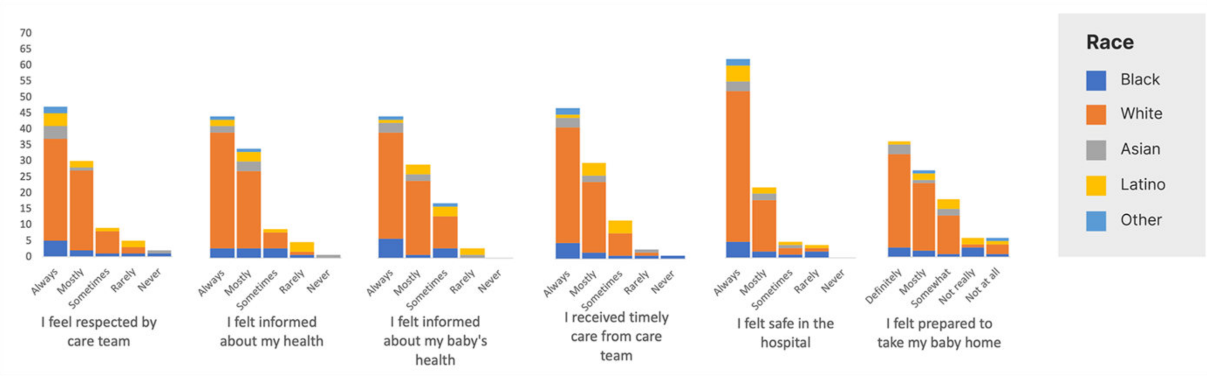


Figure 5. Exhibit in use

The results were a real-time data visualisation that displayed answers to questions about experiences in maternity care by race and ethnicity. Table 1 reports the summarised results of the survey questions by race and ethnicity. Ninety-three visitors contributed to the participatory data visualisation board. Sixty-six self-identified as White women, ten of them as Black women, nine of them as Latina, six as Asian and two as other. The results were not statistically significant, but there were trends in disparities. For example, to the question of feeling respected, three out of ten black women reported feeling respected sometimes, rarely, or never; three out of nine Latina women reported feeling respected sometimes or rarely, one out of six Asian women reported never feeling respected, while only nine out of sixty-six white women reported similar feeling.

Table 1. Summarised Data of Participatory Board



3.1 Debriefing

The design research team compiled notes from each day the exhibit was on display. Distinct themes emerged from iterative thematic coding of visitor feedback and commentary. Comments primarily fell into one of two categories: 1) general feedback regarding the exhibit and awareness on the topic or 2) commentary on personal experiences around postnatal care. Table 2 describes select example commentary from each of the themes.

Table 2. Sample visitor commentary

General Feedback
○ Visitors said the exhibit data seemed accessible and understandable to them. ○ Many visitors were unaware of the racial disparities in maternal outcomes. ○ Visitors would return to see how the data visualisation board had changed over time or bring a friend to participate. ○ Visitors stated they related to the videos that depicted postnatal care inequities.
Personal Experiences
○ Many birthing parents shared they felt forced to consent to procedures or medications with very little explanation provided. ○ A Black birthing parent reported having a good experience with a Black OBGYN. ○ A Latina birthing parent shared she felt unable to speak up about her care because she didn't have insurance. She said she had medications pushed on her and she felt guilty for not preparing herself better. ○ A Black birthing parent shared that she had preeclampsia and felt she was not taken seriously. She shared she had to have her friend, who worked in the hospital call, on her behalf to be taken seriously. ○ Two European birthing parents reported having midwives provided as part of their standard maternity care.

4 DISCUSSIONS

Designers can make the invisible visible through the use of visualisations which generate, interpret, and communicate ideas. Moreso, participatory visualisations can inspire interactions among people, build empathy, and encourage public engagement. The intention of the museum exhibit was to educate and engage museum visitors around the topic of disparities in maternity care through interactive data visualisation tools. The design research team anticipated that visitors would preview the slides on the monitor, interact with the touch screen monitor to learn more about racial inequities and then perhaps participate in the data visualisation.

Black visitors commented that they were able to relate to the situations depicted by the animated videos, and they felt like they were accurate and generalisable experiences of disparities in maternity care. This was the first time the animations were shared with the general public and validated the premise that the videos are an appropriate tool for storytelling and empathy building.

Many visitors were eager to add their responses to the participatory visualisation board. The board emerged as a powerful tool to facilitate the telling of stories and personal experiences within maternity care. The design research team anticipated that visitors would fill out the board and then leave the exhibit or have a quick chat with the team. Instead, many of the visitors answering questions on the board told lengthy, in-depth stories of the care they received in the hospital. They were also interested in their answers as their compared to the answers of others and reflected on the contrasting experiences some others had at the hospital. The design researchers witnessed partners and children sometimes hearing these stories or perspectives for the first time. Although the initial intention of the board was to have a tangible, interactive aspect to the exhibit, the design researchers discovered a new application of this methodology to elicit qualitative data.

In conclusion, this study showcased the successful application of participatory visualisation activities by a design research team in raising awareness and promoting engagement among museum visitors on sensitive topics in maternity care and postnatal care inequities. These activities fostered an inclusive experience, encouraging active participation, reflection, and contributions from visitors. Furthermore, the exhibit provided an avenue for the team to disseminate and validate their findings.

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ECOLOGICAL ETHICS AND DESIGN FOR SUSTAINABILITY: CO-HABITATION OR ROOMATES?

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ABSTRACT
Teaching strong sustainability and ecological ethics in technological higher education remains a challenging activity. This paper explores three pedagogical activities, carried out within and outside the university walls, addressing sustainability and ecological ethics within the practice of Design. Results show that ecological ethics and strong sustainability in design are both difficult to address but possible nevertheless, and that the role of facilitators in learning activities is crucial for students to gain maturity on these issues.

Keywords: Ecological ethics, pedagogy, design for sustainability

1 INTRODUCTION
Education for sustainability is a field of study that enables future designers to work for a sustainable transition of our sociotechnical systems [1]. Research shows that sustainability is in itself a wicked problem, i.e., it is complicated, multidimensional, and has no ideal answer(s). However, it is widely recognised that current global production and consumption patterns feeding a growth-oriented economic system leading to unsustainability. Therefore, design students are at the core of the solution, generating strategies for sustainable production and consumption, notably using the approach of Design for Sustainability (DfS). Learning sustainability becomes crucial for them to develop critical and systemic thinking, and to operate at the interface between multiple stakeholders with conflicting interests [2], challenging the, sometimes unsustainable, status quo at different scales.
There are multiple types of pedagogical methods focusing on developing competences in sustainability [2]. DfS is recognised as one that effectively promotes a transition towards strong sustainability; however, while implicitly integrating ethical concerns in some of its approaches, and reflecting on the ecological impact of its practice, it does not explicitly reflect on ecological ethics of its actions [3]. Ecological ethics aims to inform actions and behaviours of design students (among others) based on a self-reflection of their roles as designers, as humans, and as the intersectional beings they are, in relation with the wider ecological systems [3]; however, unlike environmental ethics [4], its practices are harder to translate from the theory. Petit et al. [5] stressed the distinction between environmental ethics and ecological ethics: while the first one focuses on the transition from an anthropocentric to a biocentric vision, the latter one focuses on building a vision where all living and non-living elements are seen as part of one functional ecosystem, an ecosophy. Using Petit et al.'s reflection, the aim of this article is to present an analytical grid that can help identify pedagogical activities that contribute to the development of DfS while carrying an ecological ethics approach.

2 STATES OF THE ART
Sustainability has become a top priority, nevertheless, there are not many academic research papers focused on the pedagogy of ethics for sustainability. An initial bibliometric analysis supports previous research results suggesting that ethical inquiry into sustainability-related issues requires a combination of methodologies from both formal and not-formal education learning, in and outside the classroom [6], [7], [8], [9]. This lines up with the conclusion of Petit et al. [5], which states that in order to learn and practice ecological (and environmental) ethics, formal education needs to get inspiration from the

popular education model, promoting learning outside the classroom**.** Popular education differs from normalised approaches to education in that it is rooted in the experiences, needs, and aspirations of community members and promotes collective action [10]. Teaching ecological ethics is a complex task in the sense that it becomes an extra layer of complexity to the already complex world of DfS. Therefore, to achieve a curriculum integrating ecological ethics, it may be necessary to use complementary methods coming from popular education's pedagogical approach. Our methodology, therefore, is based on 3 case studies, where 2 out of the 3 cases are inspired by popular education pedagogical approaches.

3 METHODS

Our methodology is structured in 5 steps. First, generating a state of the art of different pedagogical activities that are transversal to ecological ethics and strong sustainability, focusing on the 3 criteria given by Petit et al, [5]. Secondly, building an operational grid to evaluate the relevance of original pedagogical activities. Simultaneously to step 1 and 2, performing pedagogical activities inside and outside the university walls becomes step three. Step four consists of testing the grid on the pedagogical activities carried out by some of the authors. Lastly, as step five, we perform an analysis of the results.

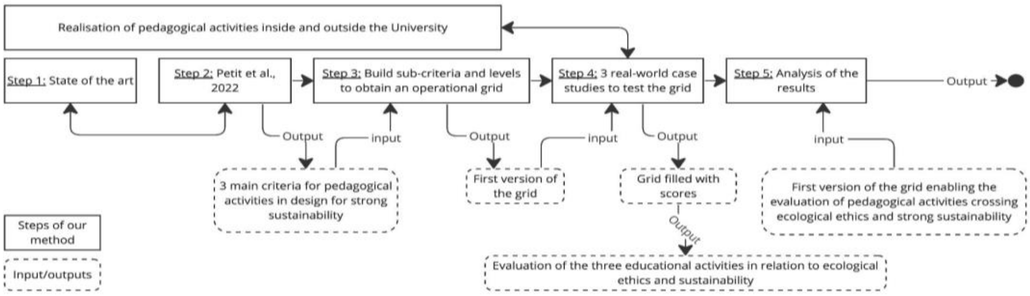

Figure 1. Diagram of steps and outputs of our research methodology

To illustrate how strong sustainability and ecological ethics can be integrated and assessed in pedagogical activities, we propose an assessment grid based on the 3 characteristics described by Petit et al. [5] of a pedagogy towards ecological ethics and sustainability:

- Breaking down the frontier between theory and practice
- Breaking down the frontier between the natural sciences and the humanities
- Breaking down the frontier around universities

The first characteristic is used to examine the gap between the theoretical objective of each activity and the observed practical results. The other two characteristics are detailed in Table 1, where they divide into several criteria, each defined by 3 or 4 levels of maturity (specific levels for each criterion).

Table 1. Assessment grid of pedagogical ethics for sustainability for design activities

Criteria / Levels	Level 0	Level 1	Level 2	Level 3
Characteristic 1: Breaking down the frontier between natural and human				
Criterion 1: Interactions between human systems and the biosphere	The biosphere is not mentioned	The biosphere is considered as a block outside of humans. Biosphere is referred to as the environment, without distinguishing between the elements that make it up.	The biosphere is seen as a set of complex interactions external to humans. Human activities understand the complexity of the biosphere while having a utilitarian relationship	The biosphere is seen as a set of complex interactions of which humans are a part. Humans are embedded in an environment
Criterion 2: Interactions	Human systems and	Humans build artefacts (action	Human is affected by	Human and artefact affect

between human and technical systems	artefacts are perceived as independent	only from the human systems to the artefacts)	artefacts (action only from the artefact to the human)	each other (two-way action)
Characteristic 2: Breaking down the frontier around universities				
Criterion 3: Involvement of local actors in a pedagogical module	No non-academic actors involved	Local actors involved in the pedagogical module (but not involved in the educational part)	Local actors involved s but a posteriori	Local actors and academics co-construct an educational activity
Criterion 4: Accessibility of knowledge for the territory	The module is proposed within the university, but it is difficult for the actors to take it up	The actors of the territory can take up what is done, but the access is not free	Territorial actors can take up what is being done elsewhere.	Local actors can take up the activity and are accompanied to do so
Criterion 5: Diversity of actors involved in the activity	Only 1 type of actor can participate (i.e., just companies)	2 types of actors can participate (i.e., 1 public and 1 private actor)	The activity can be addressed to different types of actors.	The activity is inter-generational and multicultural
Criterion 6: Level of commitment Participants: either it is free, either they paid Organisers: volunteer or in a commercial approach	Case where participants and organisers are in a commercial approach both pay or are paid to participate / organise)	Case where participants do not have the choice to participate (but do not pay for that) and there is a commercial approach on the part of the organisers (fixed price, service).	Case where the participants are volunteers. The organisers in a commercial approach - commercial: pay free price	Case where participants and organisers are volunteers to participate / organise the activity (can be free or can contribute via a donation).

The assessment grid was put to the test using the 3 real case studies described in the next section.

4 CASE STUDIES AND RESULTS

The assessment grid was tested using three pedagogical activities that already are or that can be integrated into formal educational programs. These activities have already been conducted by the authors on different typologies of students. These activities include an eco-design hackathon, which engages students in the design process from both engineering and artistic perspectives, a workshop on the concept of 'renunciation' or opting out, and a Climate Fresk, which prompts participants to better understand climate change.

4.1 Case study 1 (CS1): Climate Fresk (adult version)

The Climate Fresk is an interactive activity designed to understand the causes and effects of climate change based on the latest IPCC reports. Divided into groups, participants use a set of cards containing relevant IPCC diagrams. The objective is to reflect on, discuss and arrange the cards in the correct order to describe the most important factors that contribute to climate change, and their consequences to the environment and society. Activities were also conducted by the organisers to encourage participants to share their emotions and discuss out loud.

4.2 Case study 2 (CS2): Workshop on ‘renunciation’ (opting out)

The objective of the 'renunciation' workshop is to co-envision which existing activities from today’s society should be discontinued, and in doing so, respecting the planetary boundaries. By examining individual activities from various perspectives, participants become aware of the complexity that a 'renunciation' process carries. Ultimately, participants work together to create a strategy for ‘renouncing’ the chosen activity or certain aspects of it. Participants become aware of existing unsustainable behaviours, their consequences and potential solutions.

4.3 Case study 3 (CS3): Ecodesign hackathon

The eco-design hackathon is a 24-hour hackathon in which Master students collaborate to eco-design products or services. Topics are suggested by local organisations, promoting direct engagement with relevant stakeholders. Teams are formed mixing students from engineering schools, design schools, and master's programs with different academic backgrounds to favour multidisciplinary work. The activity also serves as the final exam for an eco-design class for some of the participants.

4.4 Results[1]

Results are described for each criterion in a table and a descriptive text. The table shows the levels achieved by each workshop: X indicates the level(s) achieved. P indicates the levels partially achieved (in very specific cases or with only one actor).

Table 2. Results about Criterion 1

Criterion 1	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)				X
Workshop on ‘renunciation’ (CS2)	X	X	X	X
Ecodesign hackathon (CS3)		X		

For criterion 1, CS1 reaches level 3 as participants map the interactions between natural systems, human and technical ones. CS3 focusing more on proposing solutions, leaves little time devoted to mapping those interactions. Finally, the level addressed by the CS2 depends on several variables: the sensitivity of the facilitator to this criterion, the topic, and the facilitator's ability to make the link between the topic addressed and criterion 1.

Table 3. Results about Criterion 2

Criterion 2	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)				X
Workshop on ‘renunciation’ (CS2)				X
Ecodesign hackathon (CS3)		X	P	

For criterion 2, CS 1 and 2 address level 3 with ease. They both connect human and technical systems and identify interactions among them. For CS3, only level 1 and/or 2 are addressed as the identification of interactions among systems is shallower. Such interactions cannot be performed at CS3 due to more time being allocated to developing solutions. For CS3 it is not certain that participants have the tools to carry out the analysis of those interactions.

Table 4. Results about Criterion 3

Criterion 3	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)	X	X	X	P
Workshop on ‘renunciation’ (CS2)		X	P	
Ecodesign hackathon (CS3)		X	P	

For criterion 3, the participation of local actors in CS3 depends on the context. However, level 3 remains difficult to address for all the case studies, perhaps because co-construction depends on interpersonal

[1] All details of the chosen case studies, as well as all the results of each learning activity can be found on the following link: https://tinyurl.com/bdmzepk5

relationships (and is therefore very specific). Moreover, the proposed activities are already designed (support, logic, sequence), which does not support an environment of co-construction.

Table 5. Results about Criterion 4

Criterion 4	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)				X
Workshop on ‘renunciation’ (CS2)			X	
Ecodesign hackathon (CS3)		X		

For criterion 4, CS2 and CS3 can be carried out by any actor in the territory. The difference between local actors lies in the support available for this activity. CS1 can also be reproduced (under a different name), but its access to the territory's actors is subject to a cost (mostly financial).

Table 6. Results about Criterion 5

Criterion 5	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)	X	X	P	P
Workshop on ‘renunciation’ (CS2)	X	X	P	
Ecodesign hackathon (CS3)			X	

For criterion 5, as the organisation of CS3 is based on the integration of different actors, the level is necessarily at least level 2. Regarding CS1 and CS2, it depends on the organisation and on the context.

Table 7. Results about Criterion 6

Criterion 6	Level 0	Level 1	Level 2	Level 3
Climate Fresk (CS1)	X	X	X	X
Workshop on ‘renunciation’ (CS2)				X
Ecodesign hackathon (CS3)	X			

For criterion 6, there is a strong difference between the case studies as they follow different participation models. The level reached by CS1 depends on the context. CS2 is positioned at level 3 because it is freely accessible and cannot be used for commercial purposes. CS3 is carried out as part of a paid training course (students) with stakeholders (companies) who pay to submit a topic, so we are at level 0 of the grid.

5 DISCUSSIONS

5.1 Breaking down the frontier between natural and human sciences (crit. 1 and 2)

In the CS1, the participants are guided, by the information displayed on the cards, to represent the interactions. In CS2, the facilitator guides the participants to highlight the interactions. For CS3, the students are mostly autonomous in the process. Reflection on the interactions between the natural, technical, and social systems are highly complex and require a system thinking approach [11]. This systemic approach may appear spontaneously to some students when they come in contact these pedagogical activities (even if this is not systematic). On the other hand, challenging an anthropocentric vision of design methods and questioning the role of the designer are weak if these issues are not explicitly raised by the facilitator. Therefore, if the activity doesn't include these elements, the link between strong sustainability and ecological ethics brought by the educational activity will be weak.

5.2 Breaking down the frontier around universities (criteria from 3 to 6)

In CS3, its activities are restricted to students of a module of a Masters-2 diploma, so while guaranteeing a diversity of actors, it does not remain accessible to external participants. Conversely, CS1 and CS2 are openly accessible but there was a lack of diversity in the participants. We noticed a segmentation of the actors taking place during the workshops (whereas it is not mandatory). This observation seems paradoxical because it shows a gap between the theoretical objectives of CS1 (open to all, mixing different types of actors) and its practice (lack of mixed interaction therefore few collective actions).

Another observation from CS3 is that students faced difficulties to feel engaged with their subject and with the company linked to the subject. Participants felt obliged to discuss a subject which was not necessarily aligned with strong sustainability or ecological ethics objectives. Thus, they felt themselves in an ethically difficult position. This issue might be due to a lack of preparation by the organisers for successfully integrating academic approaches (mostly idealistic and theoretical) from students to the more pragmatic professional world (existing within the current growth-based capitalist system). This shows that it is effectively not easy to break down the boundaries (from theory to practice) around universities on issues related to strong sustainability and ecological ethics. Such a result leads to some reflections on the preparation of students and their integration into the professional world. After participating in pedagogical experiences on strong sustainability and ecological ethics, are students more inclined to integrate the current growth-based capitalist system, or would they explore professional options that are different (i.e.: degrowth oriented)?

6 CONCLUSIONS

Thanks to this grid we can assert four elements: (1) The 3 criteria of the grid are relevant to assess DfS pedagogical activities; (2) both ecological ethics and strong sustainability are complex to address in pedagogical activities; (3) the role of the facilitator is crucial to address and link ecological ethics and strong sustainability in DfS pedagogical activities; (4) educating educators on the relationship of strong sustainability and ecological ethics is crucial for them to become successful facilitators and enable the environment for co-habitation for those concepts and practices.

The assessment grid proposed is a first draft to assess the integration of strong sustainability and ecological ethics principles in DfS activities. It is intended to be used to evaluate additional activities to better understand which pedagogical activities relate more, or less, to ecological ethics and strong sustainability. So far, the grid has allowed us to confirm that ecological ethics and strong sustainability can be assessed together (cohabitation) in DfS activities.

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NEW AUTOMOTIVE AND AERONAUTICAL MODELS AND DESIGN OF DIGITAL TWINS TO SUPPORT LEARNING IN TEC21 EDUCATIONAL MODEL

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ABSTRACT
One of the takeaways from distance learning during the COVID-19 lockdown was that virtual labs and mixed-reality lessons needed to be attractively designed. The MxRP simulator based on replicating processes of an ERP system of a virtual car assembly company, models based on Meccano, were used. Surveys were carried out with students and teachers to improve virtual and augmented reality practices. As a strategy to bring the lessons to the intramural education of the Tecnologico, or Academic Extension, models of their own cars and planes were designed to take advantage of our student's creativity. The prototypes of these models will be built by 3D printing and machining through a magnet-based clamping model to replicate the same experience in both augmented and virtual reality of the assemblies. New and models previously built by our students for automotive and aeronautical competitions will be also digitized, creating digital twins for learning. The paper shows the context, planning of process of design, prototyping, and construction of these models, with the help of students and professors of the research group. The collaboration of schools of Industrial Design, Industrial Engineering, Mechanics, and Mechatronics for creating and manufacturing these models. Technological advances lead us to replicate professions through virtual and augmented reality, as well as the creation of digital twins to increase the quality, efficiency, and manufacturing of a product.

Keywords: Digital twins, professional education, higher education, educational innovation

1 INTRODUCTION
The application of virtual and augmented reality in education has had a great boom in recent years. These new technologies have gradually displaced traditional methods [1]. But the use of these technologies does not guarantee the attention of the students. The support of didactic techniques such as gamification should be considered, to be better accepted by the new generations of students [2].
On the other hand, the use of digital twins (digital replicas of physical models) allows for a richer learning experience and with the benefits that each of these types of models and their respective means of implementation. Digital models have the ease of manipulation without the fear of wear, damage, even breaking, this through immersive and safe means. The possibility of repetition and flexibility in times that VR offers are interesting characteristics to consider. All the above makes virtual reality a widely used medium in educational and entertainment environments [3]. For their part, physical models allow the use of more senses in the learning experience, a better understanding of proportions and characteristics of the object of study, among others. It is important to mention that both physical and virtual media complement each other and allow for a better and richer learning experience in groups of students with different cognitive abilities. As already mentioned, initially models built with Meccano were used for the virtual assembly plant [4]. In Figure 1 we can see an example of a Formula 1 vehicle made with Meccano and its digital twin, to be used in the virtual assembly factory. Due to the need to

request permits and pay for licenses for the use of commercial models, in addition to considering business models in the future, we intend to develop our own automotive and aeronautical models.

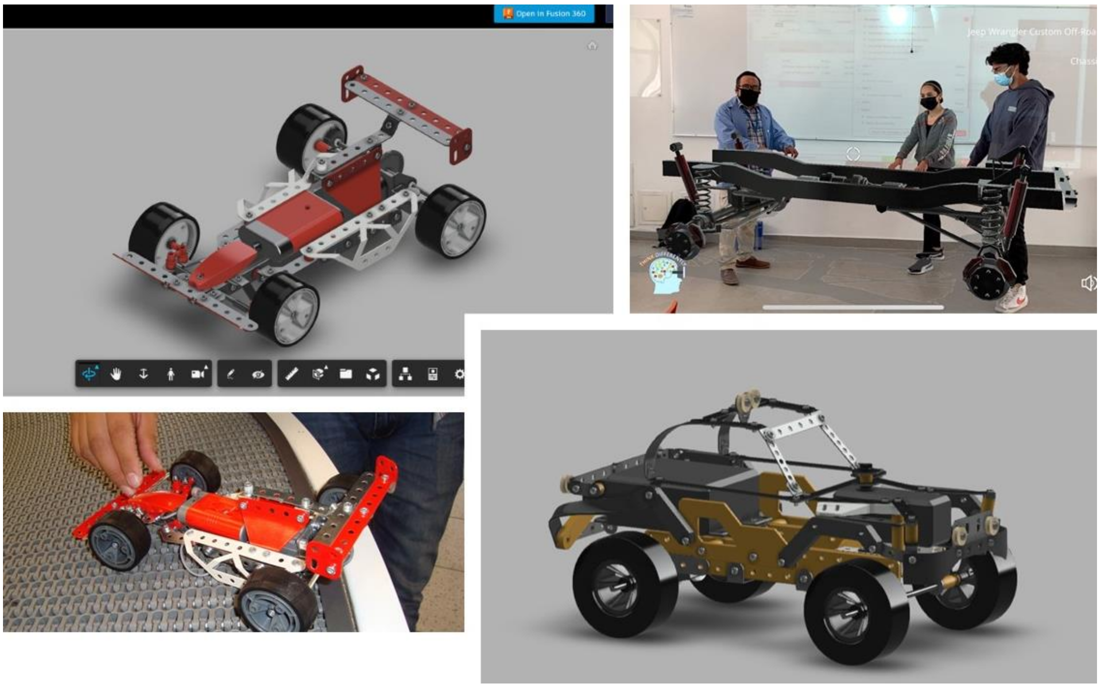

Figure 1. Formula 1 and Jeep car model built with Meccano and its digital twin

2 METHODOLOGIES

Before explaining the methodology behind this project, it is important to mention that this educational innovation proposal is supported by the Novus Fund for Educational Innovation. Novus is an initiative of the Institute for the Future of Education that seeks to reinforce the culture of evidence-based educational innovation among the professors of the Tecnológico de Monterrey, Mexico [5]. The main components of this proposal are described below, including the objectives, main deliverables, execution times, among others.

2.1 General aspects

The official name of the proposal is “Tec Assembly 21 Virtual design and scale construction of automotive and aeronautical concepts”. The proposed thematic line is Preparation for the future and the duration of the project is 16 months (since February 2023 to June 2024).

On the other hand, the educational technology that is proposed is Mixed Reality, due to the possibility of considering physical and virtual models in the learning experience. In addition, it is considered that the most appropriate instructional strategy for the implementation of these resources should be Gamification. The academic level for its implementation is Bachelor, with second- and third-year students of Industrial Engineering and Product Design.

2.2 Educational innovation proposal

The educational need can be defined as follows: In the courses that have been determined, from the academic programmes of Product Design and Industrial Engineering, being able to see complete ERP processes run in laboratories or with the training partner (company). it is not entirely possible. This is due to the ability of laboratories and companies to receive visits from students (maximum 20), so emulating these processes in simulators with virtual and physical reality at scale allows us to have active learning by being able to manipulate parts and subsystems. and not a liability with only the explanation of the training partner.

On the other hand, the traditional way to develop skills is through laboratories (mini assembly lines), physical projects (models), video analysis and visits to industrial factories. Figure 2 shows examples of car assembly activities with Meccano.

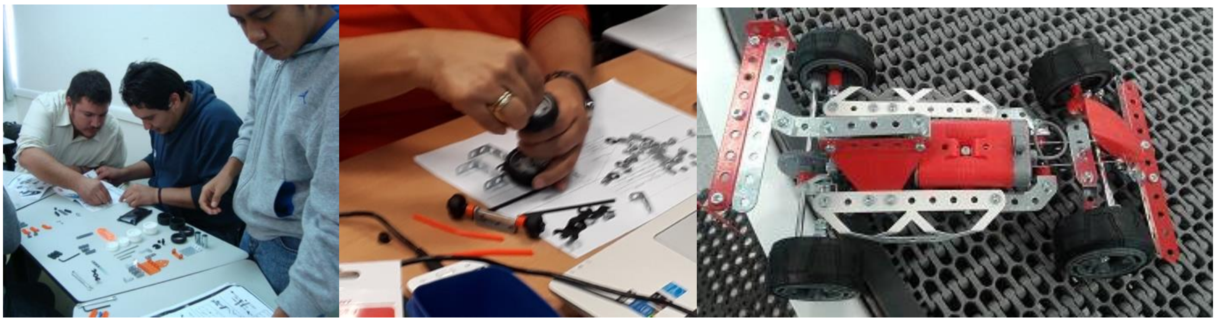

Figure 2. Examples of car assembly activities with Meccano

Based on the above, the general objective of the proposal is defined as developing virtual and physical educational models for the Tec21 virtual car assembly plant and a table game (board) for the development of skills related to the integration of systems and technologies. emerging in students of Industrial Engineering and Product Design. It is important to mention that the cars and planes will be integrated into a new virtual reality platform, project that started last year and will soon be ready for implementation.

It is considered that the innovation proposal, for its part, has the potential to be transferable since it could be implemented in other disciplines and/or levels, since it is the application of virtual/physical reality to recreate environments and dynamics that are impossible to live in the classroom, and even in visits to industrial plants. Although the initial proposal has a focus on Industrial Engineering and Product Design, due to the flexibility in terms of the focus of the activity, it may have applications in other careers such as Robotics and Digital Systems Engineering, Mechatronics Engineering, Mechanical Engineering, among others. It could also be used by graduate students in Engineering.

2.3 Administrative aspects

For the realization of this project there is a budget of $9,500 USD. This amount of money will be used for the payment of a product design student as On Campus Intern, for the development of models and manufacture of scale models. Also, for the purchase of materials for the manufacture of physical models, such as consumables for 3D printing, glues, paint, magnets, among others.

It is important to clarify that the team of teachers involved will not perceive any workload for carrying out the project. Only the On Campus Intern student will receive a monthly payment of USD 250 for each of the 12 months of work (four months per semester).

2.4 Justification of proposal

Because this proposal is an extension/expansion of two previous projects, related to virtual reality [6], augmented and physical reality [4], the educational technologies of 3D printing and mixed reality are the most convenient for the development of this innovation [7]. Figure 3 shows the initial design of the student interface of virtual assembly factory.

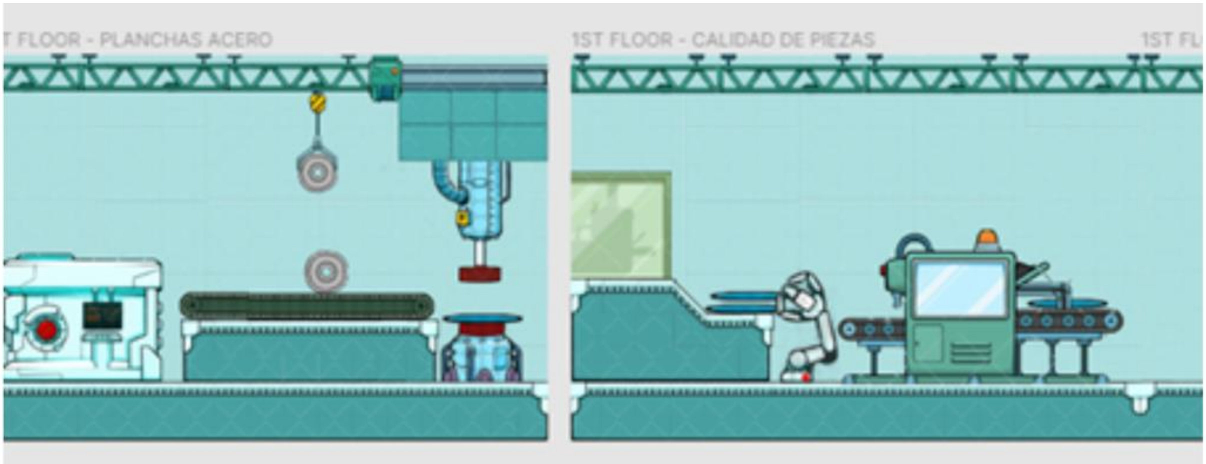

Figure 3. Initial design of the student interface of virtual assembly factory

Virtual and physical models of automotive and aeronautical concepts developed by the Institution are required in order not to depend on existing concepts patented by brands such as LEGO [8], [9], and Meccano [10].
The variables under study, for their part, are learning and problem solving, which to statistically demonstrate results, tests will be applied for the learning variable and the use of a rubric to identify development in problem solving.
Two knowledge exams focused on the practice (topic) of which we want to measure the use will be applied. The first prior to the automotive and aerospace design, the second after having carried out the design practice, to measure if there is learning and that it is statistically significant.
The hypothesis to be verified is the mean of the average of the qualifications obtained in the exams, which for the study will be called "knowledge gain"" is different between the two, being M1 before the PV and M2 after applying the PV, this is we can do by analysing the individual grades of M1 vs. M2 using a two-sample student's t-test in which we want to validate not only that they are different, but also that the mean of M2 is much higher.
For each subject, a specific practice of the virtual plant will be designed where the elements of the test (exam) are linked so that the student has a more detailed knowledge of each element and can, through experimentation, associate the theory in class with the practice offered by using the virtual plant [11], [12].
In the gamification aspect, we found that, in 2021, 70% of teachers saw an increase in student participation when using educational video games. Games, in any form, increase motivation through engagement. Nowhere is this more important than in education [13]. Other studies have found that gamified learning interventions have a positive impact on student learning, however, the impact of gamified learning interventions on student engagement varies depending on whether the student is motivated [14]. These data are relevant to our proposal as it is considered to impact a variety of disciplines and concentrations where student engagement can be increased and learning improved.
Finally, we believe that developing our own aeronautical automotive concepts (virtual and physical) will be a great contribution of added value because we will not depend on licenses and permits from companies such as Lego and Meccano. This will allow us to scale the proposal as required (continuing education) and at a given time (why not) consider marketing it. Another advantage is that these concepts will be adapted to the virtual Assembler and with the required specifications and scope.

2.5 General implementation proposal

The general implementation proposal, as already mentioned above, will consider from the months of February 2023 to June 2024, but considering only the academic periods included in that determined time. That is, the project will be carried out within the semesters February-June 2023, August-December 2023 and February-June 2024. The intensive periods of summer 2023 (July) and winter 2024 (January) will not be considered. This responds to the workloads of the teachers and students involved.
Figure 4 shows the most important aspects of the project and its distribution in the three semesters considered.

Figure 4. Initial design of the student interface of virtual assembly factory

As can be seen in Figure 4, the first semester will be used for preliminary research regarding which design parameters, components and systems, and production line that will be considered for the project. It is expected to achieve the design, 3D modeling and physical manufacturing of at least two cars and

two small aircraft. The intention of the first semester is to obtain the first car design. It will be an MCC (Micro Compact Car), due to the simplicity of its design.
Until the moment of writing this work, progress has been made in the recruitment of the second year student of Product Design who will serve as On Campus Intern; in the investigation of the components and systems to be considered in each type of car and airplane and the different types of assembly lines; as well as in the definition of the parameters to be considered for the design, manufacture and assembly of the models.
The second semester, for its part, will be used for the design of the two aeronautical models and the missing car, the incorporation of 3D models to the new virtual reality platform and the first implementation tests (this new VR platform is still under construction and is expected to be finished by April 2023). Regarding the gamification strategy, which is an important component of the complete learning experience, it will be defined based on previous experiences [2].
Finally, in the third semester, the activities will be carried out in different courses of Industrial Engineering and Product Design, the collection of qualitative and quantitative data, as well as the documentation and closure of the entire project. Publication of results in indexed journals and conference papers is also considered.

2.6 AI implementation in the creative process

In order not to occupy an existing design, teachers and students created our own automotive concept design, to work with the virtual assembly machine. Based on the Double Diamond Model of the British Design Council [15], this divergent process incorporates artificial intelligence in the generation of alternatives for the design of a two-seater car under the "microcar" segment, its two immediate references being the Renault Twizy and the Smart ForTwo. The model is graphically based on a simple diagram that depicts the divergent and convergent stages of the design process, giving the model the shape of a double diamond. The model is also called the 4D model because the name of each phase begins with a 'D': Discover, Define, Develop, and Deliver.
The way in which this principle is adapted to the development of the conceptual proposal of automotive design, lies in implementing artificial intelligence in the "Develop" phase. The discovery phase is given by the purpose of the investigation that corresponds to emulating the process of an assembly company in a virtual way. After an initial formal exploration through photos and sketches and once the automotive segment (Microcar) has been defined, we proceed to the Develop phase, where artificial intelligence is "fed" through "prompts" to generate a greater number of iterations in the process. as little time as possible, exploring the different alternatives that the algorithm produces than two different Artificial Intelligences: Midjourney and Deep Dream Generator. Before converging in the Delivery phase, the proposals are reviewed to obtain feedback from the design team, and thus, be able to determine a proposal that combines the requirements and appropriate parameters of the brief proposed in the first phase (Figure 5).

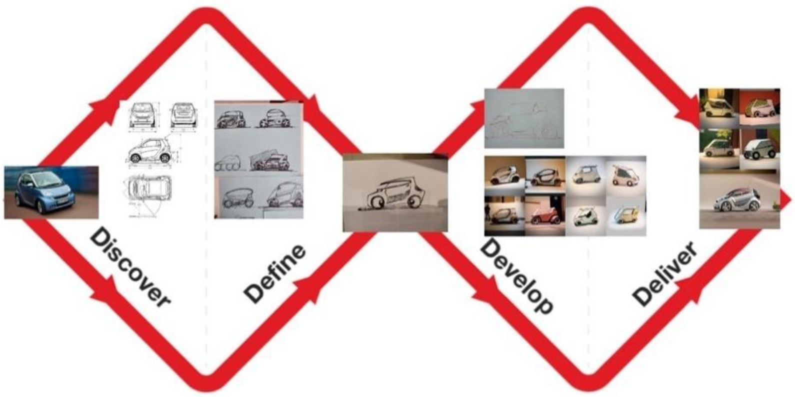

Figure 5. AI assisted double diamond model

3 CONCLUSIONS

Due to the timing of the project, there are currently no concrete results, but the authors consider it important to carry out this work to share the background, context, and implementation process of this educational innovation, to be developed at the Tecnologico de Monterrey Campus Queretaro. And precisely the Tecnologico de Monterrey, as a private system of universities in Mexico, is recognized as a pioneer in educational innovation in Latin America. The expectations we have, and based on similar experiences, is that the implementation of these new automotive and aeronautical models of our own will be well accepted by the Industrial Engineering and Product Design student population and will contribute to a better hybrid learning experience (digital and physical), with the support of virtual reality and the ingredient of gamification. It is also intended, as already mentioned, to eventually to share with others Campus of our university and commercialize the virtual assembly platform and the automotive and aeronautical models. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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AMPERSAND STUDIO: A SOCIAL DESIGN CASE STUDY OF AN ANTI-VENOM DELIVERY SYSTEM IN WESTERN AFRICA

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ABSTRACT
The Ampersand Studio is an undergraduate multidisciplinary social design studio at the University of Kansas focused on working with outside partners and stakeholders to solve large-scale and complex social problems. This case study presents a one-semester project with undergraduate students from industrial design and graphic design. Students worked with medical experts, aeronautical engineers, and human-computer interaction experts in the United States, Mexico, and Guinea to understand and design a strategy for reducing the death and amputation rate from venomous snake bites in Western Africa, specifically Sierra Leone and Guinea.
In this paper, we discuss how students defined and found approaches the partners at Talon Launch had not considered. A rapid design process that could be efficiently implemented was necessary as the stakeholders were looking to save lives as soon as possible. The students employed an in-depth research study including interviews with experts and users, which helped them understand the needs of a wide range of stakeholders. Through this process, they provided systematic design options that went well beyond the partner's initial focus on a drone delivery system. Instead of jumping to only a complex and highly expensive drone system to help address this issue, students proposed a series of solutions, which included a step, leap, and jump.
The key contributions of the paper center around how design thinking can lead to a more comprehensive range of solutions in complex and large-scale social design problems, providing stakeholders with a variety of options that can be implemented in appropriate stages.

Keywords: Social design, design thinking, drones, industrial design, antivenom

1 INTRODUCTION
This paper presents a case study of an undergraduate multi-disciplinary design studio project at the University of Kansas partnered with a non-profit and a team of professionals at Talon Launch, including herpetologists, medical experts, aeronautical engineers, and drone specialists in three countries. The project brief was to design an autonomous drone antivenom delivery system for use in rural communities affected by venomous snake bites in Sierra Leone and Guinea.
Designers often work with stakeholders who either have a pre-determined set of design expectations or are reluctant to pursue innovation or solutions outside of the initial brief scope. This project utilized design research and design thinking in conjunction with using a *Step, Leap, Jump* strategy to get buy in from the stakeholders on expanding the scope of the project, and to introduce solutions in an accessible way.

1.1 Step Leap Jump
Designers are tasked with addressing a broad range of problems when working for clients, from small aesthetic updates to large-scale system design with multiple stakeholders. Through initial research, "how might we?" exercises, [1] and investigations designers may find opportunities that would benefit the project but may push beyond the scope of the initial brief. [2] This requires designers have the ability to help the stakeholder accept innovation and broader project scopes by using clear communication, empathy, and through building trust. [3] Designers in industry often utilize a concept known as *Step, Leap, Jump* to walk stakeholders through a series of concepts that gradually expand from the initial

intent of the brief. [4] The initial concept the designer would present falls under the *Step* category. The *Step* relates closely to the initial prompt from the brief and meets the needs as stated. The designer would present the research as it relates to the *Step* design, this phase of S*tep, Leap, Jump* is critical in receiving buy-in from the stakeholder as it shows the designer sees value in the brief as it was presented and is not dismissive of the original need.

After the designer presents the S*tep* concept they advance to the *Leap* option. They present the relevant research and any initial ideation for this design direction. This concept builds on the *Step* option and/or the research making it feel incremental and having seen the Step concept the stakeholder knows their needs have been met leading them to feel more comfortable with a concept that moves beyond the brief. Finally, the designer presents the *Jump* concept, which also is presented with relevant research and/or initial ideation and is the most innovative or expansive concept from the brief. If designers only presented a concept that did not adhere to the brief the stakeholders may feel disregarded and frustrated. By presenting incremental concepts expanding or shifting from the brief accompanied with design research and thinking the stakeholder will be able to consider a broader range of solutions as they know their initial needs as outlined in the brief are being considered and met. [4]

2 CASE STUDY

In 2022 an international non-profit, Talon Launch, partnered with our multi-disciplinary studio at the University of Kansas consisting of 2 graphic design and 5 industrial design undergraduate students. They were seeking help in the design of a drone delivery system to deliver anti-venom for snake bites in rural Western Africa, specifically in Guinea and Sierra Leone. Talon Launch was working with multiple teams spread across three continents including aeronautical engineers, researchers, and medical experts. This passionate group was focused on the rapid implementation of a drone delivery system, with a motivation that every day the project waited to launch more people would be permanently injured or die from venomous snake bites. This sense of urgency initially restricted the scope of the design brief in order to ensure efficient deployment.

2.1 Project Brief

In Guinea and Sierra Leone there are over 24,000 snake bites annually causing over 3,600 deaths, and 4,600 amputations, primarily affecting children and farmers. The poor road conditions and intense rainfall in this region often lead to long travel times. What in a developed country would be a 30-minute to 2-hour drive, could easily be an 8–48-hour trip over washed-out roads that cars and trucks are unable to navigate, forcing sick and/or unconscious snake-bitten passengers to be transported on the back of a motorcycle.

The design problem is if the snake bite victim does not receive anti-venom, which costs $6,000 per vial, and blood within one hour the patient will likely lose a limb, and after 6 hours the victim will likely die. Vials of the anti-venom must be kept at a secure location at the snakebite clinic headquarters as theft is a serious issue. The main clinic had a network of smaller clinics in the surrounding area, up to 160 kilometres away, which were closer to victims, these clinics needed to quickly be sent the lifesaving anti-venom so the patient could then immediately make the trip to the main snakebite clinic for further treatment. The team had already started the development of an initial drone concept which would launch from the main snakebite clinic and hover over smaller clinics in the region dropping a payload with the necessary medical supplies.

Our students were tasked to solve for the following design deliverables:

- Payload which can be released while the drone is hovering in the air.
- Adjustment of drone's undercarriage to hold and release drone.
- Graphics to ensure public and government know it is a medical product.
- Integration of drone's batteries and system for charging.

Figure 1. Drone and Road Conditions

2.2 Research Findings

In the first phase of the project students conducted design research including interviews with medical professionals and snake bite experts on the ground in Guinea and Sierra Leone. They also interviewed drone experts in our country, as well as the experts on the team. Students conducted background research on current and emerging solutions to drone delivery systems throughout the world. They found multiple areas of opportunity that the initial project did not address. They presented areas of opportunity in a Step, Leap, and Jump format using the “How might we? methodology”:

2.2.1 Step: Areas of Opportunity

- The initial concept of the payload was investigated, with the opportunity of how might we address loss of the payload after delivery, how might we solve for visibility at night or in a storm? How might we assist in the return of the payload container?
- Students investigated graphic options currently used for vehicles and containers.

2.2.2 Leap: Areas of Opportunity

- Patients still need to be transported to the main clinic after being treated with the anti-venom. They might be unconscious while riding on a motorcycle for 2-48 hours through difficult terrain in a rainstorm. How might we design a system to keep the patient on the motorcycle if unconscious or weak?
- Certain clinics are too far away from the main snakebite clinic and the drone would not reach them. How might we store the anti-venom at key remote clinics and ensure the main snakebite clinic remotely controls accessibility to the medicine as theft is a serious issue?

2.2.3 Jump: Areas of Opportunity

- The students found the area has consistent winds which would make it impossible for the original drone to fly 50% of the time. The original drone could not reach many of the needed locations as it had a range of 50 kilometres. How might we quickly reach clinics up to 160 kilometres away even when there is intense rain and wind, land at multiple sites, drop off blood and medicine and pick up more supplies at the main hospital then return to the main snakebite clinic? When the students presented this opportunity area, they presented existing concepts that met these needs based on information from our aeronautical engineering department.

By presenting research broken down into Step, Leap, and Jump categories using the “how might we” method, the students had buy-in from the stakeholders and they were excited about what the students could do. The stakeholders knew that the work they needed to complete the payload and other immediate issues were being addressed and were more open to innovation and concepts that strayed from the original brief.

2.3 Concepts

The students moved forward with their Step, Leap, and Jump opportunities, breaking into teams of 2-3 students to work on different concepts.

2.3.1 Step: Concepts

The students designed a drone payload system as originally specified, while adding some features to solve for needs they found during their research phase. The payload could hold multiple vials of anti-venom, blood, and other supplies. It was visible at night and had a parachute for smooth landing. The payload was integrated into the body of the drone and had a quick charge system with a removable battery. The clients have integrated this design into their drone and are moving forward with production. Although this design will not reach all the needed users it will be effective at vastly improving the situation on the ground, can be implemented quickly, and is more economical to deploy.

Figure 2. Step: Final Payload and Drone Concept

2.3.2 Leap: Concepts

After finding a need for immediate remote access of medications at key clinics, students designed a locker cabinet system which only the central snakebite clinic could unlock as can be seen in Figure 3. This would be refilled when supplies run low and would prohibit theft of the $6,000. per vial antivenom. Often patients need 2 vials of venom before they can make the trip to the snakebite clinic. This system had not been considered by the nonprofit group as they had settled on drones early on, they are implementing a similar system moving forward.

Figure 3. Leap: Lockbox System

A simple motorcycle harness was also designed, this is based on straps used by the military to move injured bodies and is simple and adjustable so children and adults can be safely transported even if they are unconscious from the smaller clinics to the main snakebite clinic. A key feature is the need for this system to fit into the limited space of the drone payload.

Figure 4. Leap: Harness

2.3.3 Jump: Concepts

Students collaborated with our aerodynamic engineering department to create a concept, shown in figure 5, which can meet many of the needs of the snakebite clinic including the ability to fly through intense rain and wind. It can travel using its combustion engines up to 100 miles making multiple stops to drop off anti-venom and blood along the way. Its durable design can withstand harsh conditions. This concept is being used by the non-profit to fundraise for a more robust drone based on this design.

Figure 5. Jump: Concept Drone

3 CONCLUSIONS

This paper is a case study of how designers can present research and concepts which extend beyond the initial brief. Initially, the students felt pressure to solve all of the needs of the user at once, the added context of saving lives made it difficult for them to initially focus on meeting the immediate needs of the brief. The *Step, Leap, Jump* methodology enabled the students to design to the original brief and systematically expand the scope of the project based on their broad initial research. By breaking research and ideation into categories students were able to keep their Step concept closer to the brief and integrate more innovative ideas which might have been too far outside of the initial brief to the Jump concept. This process led to a more comprehensive range of solutions for a complex and large-scale social design problem.

Partners on the ground in Guinea and Sierra Leone and at Talon Launch were pleased with the project meeting their immediate needs as well as with the additional scope of the project that our students investigated. They reflected that the initial research presentation formatted in Step, Leap, Jump in a "How might we" format made them feel more comfortable with the project scope expanding. They believed their pressing needs were being met and they were being heard, but also felt included in the design process by the research being presented in a broader question format. The design process did not include co-design with the partners, but the research felt the design outcomes were less prescriptive and more investigative. They were excited by the Step, Leap, Jump methodology and appreciated the

breakout of concepts, it made it easy for them to navigate possibilities and how different ideas might be strategically deployed.
The students also learned how to present concepts that are beyond what the immediate ask was from the partner. In design we are often working with partners who may be hesitant, these partners were excited about the possibilities and saw potential in many of the concepts the students presented. They also were provided a variety of options that could be implemented in appropriate stages. Often industry partners may be hesitant to take risks or push for innovation. A Step, Leap, Jump method can help walk them towards concepts which are out of their comfort zone and show that the designer is able to meet them where they are while showing them where they can go.

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A COMPARATIVE ANALYSIS OF DESIGN AND MANUFACTURE TEACHING IN MECHANICAL ENGINEERING

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ABSTRACT
This paper draws parallels and contrasts between the Design and Manufacture (D+M) focussed learning tracks of the Mechanical Engineering courses at Nottingham Trent University (NTU) and Imperial College London (ICL). These two institutions have historically had a different focus and vision. At NTU, various engineering courses undergo the same D+M module with the aim of delivering well-rounded engineers who have specialised within their own discipline and have acquired skills and knowledge in areas that are considered slightly outside their domain of study. D+M teaching is approached as a tool to encourage creativity across disciplines, within the themes of sustainability and robust product development. The objective is to remove inter-disciplinary barriers with the appreciation that problems of the present and future require pragmatic solutions from creative problem-solvers who are not limited by their disciplines of study. The Mechanical Engineering course at Imperial has a strong emphasis on theoretical and mathematical foundations, with D+M modules aiming to integrate knowledge obtained and to bring this theoretical knowledge into practice. Additionally, the students achieve competence in engineering drawing, standards, design methodologies, and workshop skills, as well as transferrable skills. The objective is to develop mechanical engineers who combine strong analytical foundations with innovative product development skills. Based on a comparative analysis of the two programmes, a two-axis digital/practical-breadth/depth map and a learning outcome map have been developed. These can enable D+M Module Leaders and Course Directors at different institutions to make more informed decisions about teaching, content, delivery, and the student journey.

Keywords: Design and manufacture, learning outcomes, pedagogies

1 INTRODUCTION
Mechanical Engineering is one of the traditional disciplines within the engineering sciences, and covers a wide variety of sub-branches, ranging from production to combustion and from nuclear applications to biomedical implementation. A typical mechanical engineering curriculum combines foundational topics, such as stress analysis and thermofluids, with modules that have a more practical and/or creative focus. These more practical and creative aspects are often taught as part of the Design and Manufacture (D+M) modules, which often take a more open-ended approach than the core, foundational modules. One of the objectives of the D+M modules is to provide students with the space to start understanding the roles of an engineer within society and help them overcome any thresholds in learning. These practical modules are not necessarily best assessed using traditional paper-based exams, and commonly followed approaches to these practical modules include problem-based learning, project-oriented learning and design-based learning. In this paper we describe and analyse two different approaches to D+M teaching, using the Mechanical Engineering courses at Nottingham Trent University (NTU) and at Imperial College London (ICL) as case studies. These two institutions have historically had a different focus and vision, and as a result differ significantly in their pedagogic approach as shown in Table 1.
The NTU Mechanical Engineering course is accredited by the Institution of Engineering and Technology (IET) and meets the academic requirements for registration as a Chartered Engineer. The course is also recognised by Conceive-Design-Implement-Operate (CDIO), a framework that encourages a project-based learning approach [1]. At the heart of the course are four core values: tools,

skills, creativity, and delivery. These are disseminated through a combination of engineering foundations and engineering applications entrenched throughout the curriculum. As opposed to traditional Mechanical Engineering courses, there are no explicit D+M modules in this course, instead these skills are embedded within a number of modules. The course dedicates a third of the year's academic credit to practical and project-based learning modules in each academic year, with half the year's academic credit dedicated to a project-based learning module in the final year of study. The project-based modules are shared amongst all NTU engineering courses (Electrical and Electronics Engineering, Sport Engineering, Biomedical Engineering and Mechanical Engineering). In addition to this, project-based learning is part of other core and specialist modules. This extensive focus on project-based learning is to inculcate team working, communication, project and time management skills in budding engineers while also enhancing technical and practical expertise via active learning.

Table 1. Comparison of design and manufacturing teaching at NTU and ICL

Features	NTU	ICL
Courses	BEng (Hons), MEng (Hons); with optional provisions of foundation and placement years	BEng (Hons), MEng (Hons); with an optional placement year
Disciplines	Sport, Biomedical, Electrical & Electronics and Mechanical Engineering	Mechanical Engineering only
Focus	Strong focus on design processes and methods. Workshop skills are acquired primarily via project-based learning	Engineering drawings, standards, design processes and methodologies, and workshop skills
Project Type	Recurrent themes of interdisciplinarity and collaborative learning through group work and some individual coursework	Evolution from individual work in year 1 to group work in year 2 and multi-level supergroups in year 3
Teaching Style	Primarily project-based learning with very little didactic teaching	Project-enhanced learning to apply and broaden didactic teaching

The Mechanical Engineering course at ICL is a four-year Integrated Master's course, with minimum entry criteria of A-levels awarded at A*A*A or 40 points in the baccalaureate. The curriculum has a strong emphasis on theoretical and mathematical foundations and takes a scientific approach to engineering. The course is accredited by the Institution of Mechanical Engineers and meets the academic requirements for registration as a Chartered Engineer. The programme has a core D+M module in each of the first two year's worth a sixth of the year's academic credit with the third year D+M module being worth a third of the year. The main objective of these three D+M modules is to integrate the theoretical knowledge obtained and to bring this theoretical knowledge into practice. In the first-year module, the students work individually to achieve basic competence in practical topics such as sketching, engineering drawing, standards, design processes and methodologies and workshop skills. In the second year the D+M module comprises two team-based projects, exposing the students to teamwork, project and time management and budgeting next to deepening their Engineering Design and Manufacture competencies. In the third-year module an additional layer of teams and required accountability is added as the students deliver a large engineering 'superproject' comprising three collaborating teams of four students. The objective of the three years is to provide a framework enabling a naturally evolving skillset that develops young mechanical engineers who combine a strong theoretical foundation, analytical skills, and the ability to utilise their knowledge to develop innovative products.

Both courses adhere to the UK Engineering Council Accreditation of Higher Education Programmes, fourth edition (AHEP4) [6]. The AHEP4 guideline defines 18 learning outcomes for a four-year Integrated Master's course and is widely used by UK Higher Education Institutions to define and assess their programme. Most of the learning outcomes have a direct or indirect link to D+M related modules. However, the methods used to achieve these learning outcomes are not specified in AHEP4 and the approach is decided by the educators. The aim of the present study is to analyse the D+M focused teaching within these two Mechanical Engineering programmes, which have traditionally had a different focus and approach. The study is aimed at creating an engineering design education framework that can be used to select a student-focused pedagogy.

2 METHODOLOGIES

The study was conducted in two phases. In the first phase both institutions provided documentation describing how design is taught within their department. This documentation detailed each design module on the course, the year in which it is taught, which engineering courses it is compulsory for and whether it is available as an elective for any others, its syllabus, the module learning outcomes and primary teaching methodologies. A comparative analysis of this information was carried out, allowing for commonalities to be identified as well as areas of significant difference. As both departments hold accreditation, the AHEP learning outcomes were also used as a framework to provide a common set of terms in this comparative analysis process. This enabled differences in phrasing and terminology to have a minimal effect on the analytical process. Once the first phase had identified the areas of most significant difference, as well as common themes, this enabled questions to be constructed to facilitate an interpretative phenomenological analysis via focus groups led by an independent researcher, who has been at ICL for less than a year and does not lead a design module and was therefore considered sufficiently independent to lead the focus group style discussion. The other two researchers are the educational leads for the design efforts within their departments and were therefore the participants of the focus group. As the process of teaching affects our perspective on its purpose and efficacy, as well as our understanding of the syllabus content, the phenomenon under analysis was design teaching, and the context was the respective institutions. Thus, the focus group discussed the key differences identified and the outcomes of this discussion analysed to gain a deeper understanding of the relevance and significance of the differences and commonalities of the courses.

3 RESULTS

The two institutions vary in terms of the breadth of design skills taught relative to the depth or detail this teaching goes into. In addition, the focus of the specific learning outcomes is different. When mapped onto a Venn diagram dividing the learning outcomes into three themes "Engineering Analysis", "Engineering Practice" and "Engineering & Society" these NTU-specific learning outcomes have their gravity at the intersecting central area of the diagram, see Figure 1(a). This correlates with the holistic nature of project-based learning instilling integrated skills. ICL covers fewer topics with an emphasis on Engineering-Practice based content, see Figure 1(b). This content is a continual focus year on year, resulting in a greater depth of understanding being attained in these areas and correlates with the institutional focus on scientific expertise.

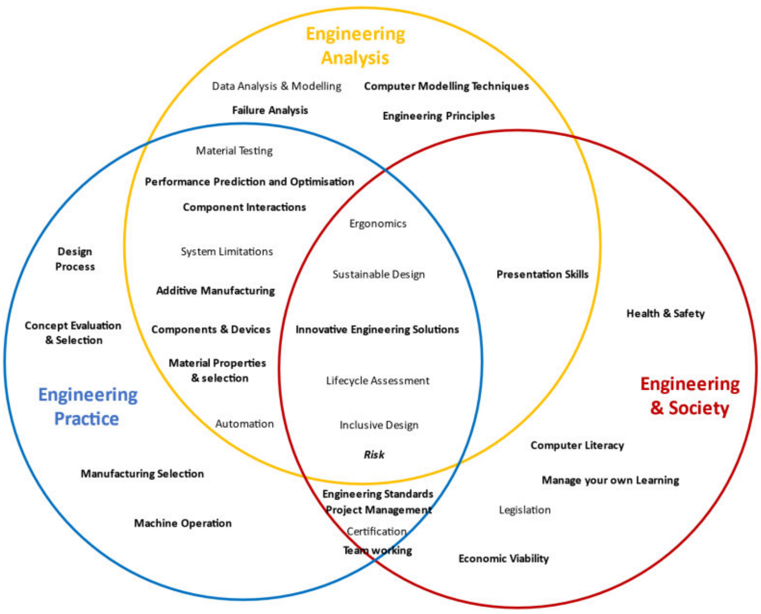

Figure 1. (a) NTU

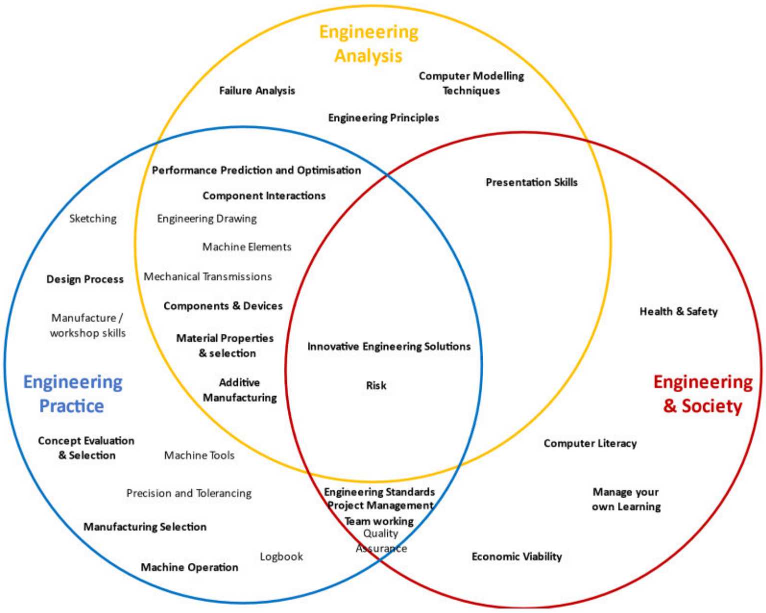

Figure 1. (b) ICL

Figure 1. Division of learning outcomes over the themes "Engineering Analysis", "Engineering Practice" and "Engineering & Society". Bold font indicates learning outcomes shared by both institutions

A related divergence was identified in the nature of the application and deliverables, with NTU focusing on digital skills including virtual prototyping, digital optimisation and CAD for additive manufacture. ICL on the other hand requires that students pass a module covering practical workshop skills, and subsequently use these skills in their second, third, and optionally in their fourth year, to manufacture functional physical prototypes. The two axes of skill development can be visualised in Figure 2 below:

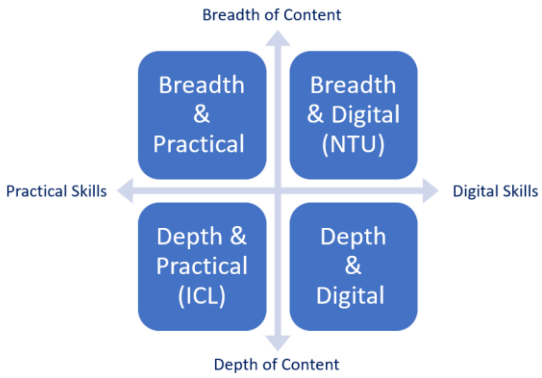

Figure 2. Two axis Digital/Practical-Depth/Breadth Chart

Due to constraints on teaching time and resources within a degree course educators must make choices between topics and methodologies. The chart maps out the resulting divergences in skill areas identified though our analysis, and the emerging foci of D+M teaching. As an example, NTU covers a much wider range of design topics, including sustainable design, inclusive design, automation, and anthropometrics and assesses students on virtual/digital artefacts such as 3D models and online showcases, hence is located in the top right "breadth and digital" sector. ICL covers fewer topics but goes to greater depth, such as selection of bearings and implementation of drawing standards. Students are assessed using physical prototypes and test events, hence ICL is located in the diametrically opposed "depth and practical" sector.

4 DISCUSSIONS

The rapid evolution of knowledge in the 18th and 19th century resulted in specialisation within the field of engineering [2]. Over time, the establishment of 'mainstream' engineering disciplines such as Mechanical, Chemical, Electrical and Electronics Engineering as well as policy, and cultural differences have resulted in the development of silos within engineering and engineering education [3]. However, the emergence of the fourth industrial revolution has resulted in the renewed spread of interdisciplinary approaches within engineering [4] and indeed, the acquisition of interdisciplinary skills is regarded an important objective of contemporary scientific and engineering education [5]. Compared to previous iterations, the learning outcomes of the fourth edition of AHEP have a greater emphasis on inclusive design, innovation, sustainability, and ethics. Within a societal context, AHEP4 places a stronger focus on equality, diversity, and puts forth explicit learning outcomes for security and the mitigation of security risks [6]. This requirement for increased awareness of ethics and the society at large has brought a focus on interdisciplinarity to engineering education. The broad and integrative nature of D+M focused modules means they often become a compendium for the wide range of practical and transferrable skills that do not have an obvious home within the theoretical and more engineering science-focused modules. Whilst this may have certain benefits, such as allowing the students to experience engineering to its broadest extent and without many of the constraints of classroom teaching, this approach may also result in a lack of focus for these modules, and in some cases students perceive these modules as having insufficient engineering content. This affects the student journey and diminishes the efficacy of teaching. In addition to offering core Mechanical Engineering modules such as Thermodynamics and Solid Mechanics, a significant proportion of the curriculum at NTU focuses on project-based modules that are shared amongst all engineering courses. Without being explicitly D+M focussed, these modules cover a myriad of D+M topics. As an example, the project-based learning modules culminate in a three-week long 'Grand Challenge'. In this project, students are put in cross-disciplinary and cross-year teams to devise an innovative solution to an existing challenge. Some themes covered in the past include energy harvesting, sustainable development, and wireless networks. Within the general theme, the student groups focus on a sub-theme such as medical devices or space and exploration. The deliverables are a group presentation in a tradeshow, a promotional video, a business model canvas, and a demonstrator that acts as a prototype of the solution devised. The themes are deliberately kept broad and not restricted to a specific discipline, enabling students from various engineering backgrounds to come out of their disciplinary silos and integrate their knowledge to produce innovative solutions. For instance, a Mechanical Engineering student would bring specific skills and knowledge to the project but also gets an opportunity to learn and apply skills and knowledge from the other disciplines. Consequently, the presented solutions are the result of an integrated engineering approach. In devising their solutions, the students must also consider factors such as ethics, budgeting, marketing and promotion, communication, presentation, and user experience. The integrated curriculum encourages interdisciplinarity and has agility to adapt to and include new learning outcomes, such as equality, diversity and inclusion. However, catering to a range of engineering courses within the same project means that the depth of the content can be compromised. As an example, these modules may focus more on inclusive, sustainable and user-friendly design but might not explore the specifics of machine elements.

ICL has a more traditional programme, with the curriculum comprising core Mechanical Engineering modules. The D+M journey of the students evolves from introductory in the first year to a project simulating a real engineering design studio in the third year: In the first year the D+M content has a similar structure as the foundational modules, with a focus on machine components, tolerances and fits, manufacture, as well as engineering drawing and CAD. In addition, the students complete a five-day introductory workshop skills training. The module is assessed by completing an individual design assignment. In second year, the integrative nature of design is introduced, with students first working on an introductory Design & Make group project that builds on first year experiences and adds teamwork and project management components. The module is subsequently concluded with a week-long full-time intensive group design project, with as deliverables five daily reports, an oral presentation, a poster presentation, and individual logbooks as well as a self and peer assessment. The third-year D+M module covers 33% of the year, and the students work throughout the year on delivering a large innovative project. This includes designing, making and testing a prototype product that is integrated in a larger so-called 'superproject', comprising three teams of four students. Project topics have a strong mechanical focus and range from a functional wind tunnel to a human-powered hydrofoil. The project builds on the strong theoretical knowledge that the students developed in their core subjects, and includes aspects such as customer-interaction, project management and budget and acquisition responsibilities. The module concludes with an exhibition and a customer presentation of the developed prototype.

Whilst the delivery of the Mechanical Engineering programmes at the two institutions is clearly different in terms of method, content, and student journey, there are also many similarities. Design modules are often used as the catch-all subject for teaching and assessing transferrable skills such as teamwork, project management, communication, and presentation, which the students do not perceive as core engineering skills. The D+M modules are not typically assessed using a traditional paper-based exam, but often comprise an engineering focused project that is assessed in terms of a client-oriented delivery. This enables students to experience engineering practice akin to industry. For many, this is how they learn what engineering truly means, thus crossing the threshold to becoming an engineer and gaining more value from their studies [7].

Limitations to this study: The study presented is the outcome of a series of focus group discussions on the structure and delivery of Design and Manufacture modules at two institutions in the UK, using the AHEP4 guidelines as the starting point. These two institutions have taken a distinctly different pedagogic approach and have a markedly different student body. The aim of the study was to explore differences and communalities in the programmes, without bias, criticism or judgment. Consequently, the size of the focus group was deliberately limited to only include three experienced D+M educators and thus it should be noted that the results presented are qualitative and do not hold any statistical value. It is envisioned that the presented overview may form the basis of a wider exploration that incorporates other institutions, both within the UK and internationally, and also includes opinions of current and past students as well as employees and marketeers.

5 CONCLUSIONS

The two Mechanical Engineering programmes compared in this study have significant differences in the delivery of their Design and Manufacture modules. At the same time, both institutions deliver a UK-based accredited Integrated Master's degree in Mechanical Engineering, meaning there are also significant communalities. Both institutions deliver open-ended collaborative design projects that require integrative skills and creativity and that enable the students to develop practical skills as well as experience the role of engineers in society. The skillset expected from a modern Mechanical Engineer is currently rapidly evolving, meaning educational programmes will need to evolve and develop, introducing new content and consequently also having to choose which topics to reduce or even abandon. The digital/practical and breadth/depth chart and the learning outcome mapping in the Venn diagram can provide Mechanical Engineering educators with an initial development tool, enabling them to make more deliberate and informed decisions about teaching, content, delivery, and the student journey. Such decisions may be dependent on institutional strengths and expertise as well as pedagogical requirements for the typical student body at that institution, and this variety can be seen as beneficial. The diagrams may also form the basis for a more extensive mapping operation of mechanical engineering design teaching across international institutions.

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25TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
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POST-ANTHROPOCENTRIC DISCOURSES IN DESIGN EDUCATION: A WOOL-CENTRIC WORKSHOP

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ABSTRACT

This paper reflects on alternative approaches in design education and how it can shift to include current discourses of post-Anthropocentrism, through a review and reflections in current design education. Furthermore, it introduces a speculative design workshop conducted to introduce an alternative concept to students. While design is still considered a human-centred field and practice, many theories challenge human-centred approaches, such as non-Anthropocentric and post-Anthropocentric discourses that place nonhumans in a non-hierarchical order with humans. Apart from a small number of courses and workshops, post-Anthropocentric approaches are not included in the design curriculum. Therefore, there is still a need to address how design education can deal with the Anthropocene itself, and how post-Anthropocentric approaches can be introduced to students. Accordingly, to challenge traditional human-centred methods in design, the paper reflects on how design can shift to other directions with current discourses, reflecting on post and non-Anthropocentric discourses and design education. It gives examples from a workshop conducted to trigger speculative interactions with wool material, extending to how post-Anthropocentric approaches could be introduced in design education, and to educate designerly thinkers.

Keywords: Design pedagogy, post-Anthropocene, non-Anthropocentric design, design thinking

1 INTRODUCTION

The age of the Anthropocene, the geological age marked by the human impact of human exploitation on nature [1], leads to the question of how to deal with the consequences of it and shift our thinking to acknowledge its consequences on the environment. In design, scholars have started to reflect and work on how design can shift to non or post-anthropocentric approaches. However, in design pedagogy, there are not many examples that consider how to involve post-anthropocentric approaches in teaching. This study is an attempt to propose how design pedagogy can reflect on the post-Anthropocentric thought.

While there are recent studies in design that consider posthuman and more-than-human elements, the main paradigm in design is human-centred design since 1980s [2]: Human-centred design was seen as a shift from technology-centred design that focuses on user experiences; however, recently, human-centrism was questioned and challenged as it is not inclusive of nonhumans. Roudavski claims that since the consequences of the Anthropocene are undesirable and humans and nonhumans will have to live with them, a reasonable response would be to change current "human practices" [3: 148]. He points to the significance of design and the "*need for a transformation of design practices*", suggesting interspecies design [3: 147].

Although industrial design was commonly associated with industry at the end of the nineteenth century, the profession of the industrial designer was still not defined at that time, and artists, architects, craftsmen, inventors were labelled as what an "industrial designer" does [5]. Only at the beginning of the 20th century, the legitimacy of the industrial designer surfaced as a person who integrates all these activities, combining the dimensions of technology, user, aesthetics and business. [6] Heskett defines industrial design as "*a process of creation, invention and definition separated from the means of production, involving an eventual synthesis of contributory and often conflicting factors into a concept of three-dimensional form, and its material reality, capable of multiple reproduction by mechanical means"* [4: 10]. Industrial design profession links to the development in *industrialization and* *mechanization,* which began with the *Industrial Revolution*. As the start of the Anthropocene traces back to the Industrial Revolution, the field of industrial design is directly linked and should rethink how to solve issues caused by the Anthropocene.

2 NEW APPROACHES AND CRITICISM IN CURRENT DESIGN DISCOURSES

While the foundations of industrial design education relates to craftsman traditions, for the last 50 years, it has been shifting to several directions, as a result of changing issues, themes and discourses. With the new age, design field has become more transdisciplinary, and design's relationship with craft, art, natural sciences, social sciences are becoming blurrier. Many scholars agree that design should go beyond the industry limitations and reflect on future practices and challenges. As Atkinson [7], states, we are in a post profession era, and the definitions of design, designer and professions became more fluid. *"It has to be acknowledged that we are already in an new age of open source systems, shared product development and free distribution. The old rules no longer apply."* [7:153]. Similarly, many agree that design education should go beyond the current practices and industries. For instance, although sustainability as an issue has been put forward, in design education, it is often not introduced to students sufficiently. Walker [8] states, except for some examples, relatively few schools have sustainable design as a core in their curriculum. He criticizes that design research and teaching are still ignoring many issues we face today, by asking where today's design schools and researchers are: "*In my experience, most design teaching is feeding the machine – sticking to the outdated playbook of modernism, training students in skills for industry now rather than preparing them to contribute thoughtfully to a less materialistic future."*[8: 4] Additionally, he criticizes that sustainability is taken as an "*afterthought*", added to some pre-existing courses which *"serve to maintain the status quo"* [8].

Buchanan discusses a misunderstanding that design education should follow the design practice, and states that "when properly understood and studied, design provides a powerful connective link with many bodies of knowledge. Design integrates knowledge from many other disciplines and makes that knowledge effective in practical life" [9: 66]. This statement connects well with the designerly thinker, explained by Dutton and Tovey [10, 11]. Dutton writes by exploration, the student is not guaranteed to be a *"better designer",* but "*he/she has definitely begun to be a designerly thinker. It is these kinds of evaluations based upon the observation of the growth of knowledge and understanding which should become among the measures of design learning"* [10: 119]. Oxman states; *"if we are design educators, we must find means to supplement traditional pedagogy by educating the designerly thinker as well as the maker of designs*" [12: 120].

3 NON-ANTHROPOCENTRIC APPROACHES IN DESIGN EDUCATION

This study draws from the idea that design education is not only for raising professionals for the industry, but it also teaches a way of thinking. What design schools teach does not have to be limited to designing objects or systems. As an extension, the study claims that emerging discourses should be introduced to design students when they are being educated on current design issues, as a knowledge base. As design itself is not in a post-Anthropocentric era, there are some discussions among scholars how designing from non or post-Anthropocentric views is possible, and if it might be helpful for them. However, it is argued that thinking and reflecting on these frameworks could offer designers to understand ethics based on non-hierarchical and non-binary definitions of nature-culture, and worldviews on how to approach natural entities in equal ways. These frameworks can provide alternative views on how to design for new eras, for all designers and design students.

According to Walker [14], the current consequences of economic growth, such as mass manufacturing and consumption promotion are leading to destructive courses, such as environmental destruction and pollution. To overcome this exploitation, he defines two current "exits" as alternatives. First, he brings up eco-modernism as the first exit, which offers "science-based technological solutions" to our existing dilemmas. As a second exit, he brings up the term sustainable development, which involves technological improvements and results with socioeconomical benefits. However, he finds some problematic outcomes of this and states that it is limited by its conventional thinking and vision. As an alternative to these 2 approaches, he proposes a third exit, which brings up a change of priorities and values. This involves recognizing consumerism relates to the idea of development rooted on material benefits, which also destroys the world. He suggests this third exit as turning to "inner development" and questioning ideas of innovation [14], bringing up values such as making and maintaining things, sufficiency and localization. While this exit is not primarily related to post-anthropocentric discourses, the author brings up the idea that post-anthropocentric and more-than-human worldviews in design can also shift our understandings of the world and change our behavior and how we design things. Therefore, the study proposes that design education can acknowledge these alternative approaches and educate future "design thinkers" to be informed about different ways to tackle with current world issues, and this involves the introduction of post and non-anthropocentric frameworks.

Some examples from modern design education focus on issues related to sustainability and the re-use of resources, for example, many courses encourage the use of alternative or waste materials, to introduce more environmentally responsible and eco-sensible design practices. These inspire fruitful discussions on how design impacts the environment and natural resources and emphasize practices such as circular and sustainable design and use of renewable resources. Still, these approaches often consider sustainability and design as a part of consumerism, with aims of development and economic growth. On the other side, post/non-anthropocentric worldviews do not focus on human development, but rather, take on non-hierarchical and ethical frameworks that recognize the relationships between nonhuman entities, environment and humans. Furthermore, they challenge the traditional design approaches, which are dominantly under anthropocentric assumptions.

As an emerging discourse, post-anthropocentric thought is not commonly brought up in design curricula. From a literature review, examples were found from different locations, that consider nonhumans as relevant actors in design: In 2022, the conference Counterparts: Exploring Design Beyond the Human addressed ways to challenge a "one world reality", aiming to explore "*what happens when we shift away from human-centred and universalist views of design and begin contemplating future ways of co-existing and co-emerging with others on this planet*" [15]. In "A material-centric approach in non-anthropocentric design", the results of a workshop for design students is discussed, which proposed a "speculative, material-centric design approach to engage discussions towards post-Anthropocene scenarios by rethinking the entanglement of human and non-human actors" [16]. However, as post-anthropocentric discourses in design are still emerging, examples from design education are still limited. For instance, in Turkish context, industrial and product design departments usually aim to provide skills that satisfy the requirements of the industry and the user needs. "*Being aware of the social and environmental problems caused by the dominant mass production and mass consumption cycles throughout the 20th century and also the 21st century"* [13], many departments started to involve sustainability in their curricula. Nonetheless, this inclusion is still driven from eco-modernism, sustainable development, or economic growth purposes.

4 A WOOL-CENTRIC WORKSHOP OF SPECULATIVE SCENARIOS

This study discusses the results of Making Felt Castles workshop, conducted by the author for a non-anthropocentric framework, where the students worked with wool material to engage with speculative and non-anthropocentric approaches. The workshop took place in Istanbul Bilgi University, Turkey, and was a part of summer internship courses in 2019, organized by the research assistants of the faculty. On total, 8 workshops with various themes were opened by different instructors, and students made their top 3 choices based on their interests. This workshop was proposed from the department of industrial design, still, students from the whole faculty were welcome to join. Initially, 27 students applied as their first choice, and a total of 20 students were selected to attend the course. The students were primarily in their first year, from departments of industrial design, architecture, and interior architecture. Most of the class were from Turkey, except for two foreign students not familiar with Turkish language. Accordingly, English became the main language for presentations and juries during the workshop. The workshop consisted of many complementary exercises to get to know felting and materials in design. However, in this study, the main exercise and some of its results will be shared. Design brief for this exercise as a group project was as follows,

"In this workshop, you are expected to design a planet for a wool-based life form, a creature evolved to suit the life on this planet, the living area of this creature and the daily life objects it uses. In the end of the workshop, you are expected to present the daily life of this creature, and how this planet has its life cycle. We (human beings) are carbon-based creatures. But our support structure is also based on calcium and many other inorganic materials. Takes this example into consideration."

The main aim of the 2-week workshop was to change the narrative of our current world scenarios to focus on wool material as the main substance, and the main topic was worldbuilding for wool-based life forms [17]. It also intended to introduce students to felting method and wool material. For the method, the wool-based life form was inspired by speculative design approaches through a traditional and contemporary craft method, named felting. Felting was chosen as it allows for a direct hands-on approach with wool material, it requires minimal tools. For felting, unlike some other textile making methods, wool material is applied without being spun, therefore students have a chance to experience the qualities and tactile feelings of the wool fibres. Also, the instructor had previous experience with the method as she experimented with it in previous years for her design practice, which allowed her to pass her own experiences to students. By doing the workshop, three outcomes were anticipated. Firstly, it aspired for students to interact with wool material in a non-conventional way. Secondly, it aimed to find out how to use wool and felting in out-of-ordinary situations, and if it could lead to different engagements with the material itself. When felting is made in this non-conventional way, it was foreseen that it could change our perceptions of felting practice itself, and how we perceive the material. Thirdly, it intended that using material and production techniques with speculative methods could trigger students' wish to continue experimenting with the dying craft of felt making.

Students were asked to think of a scenario for a wool-based life form and design a planet, in which this wool-based life form can exist in. Furthermore, as the wool-based life forms progressed, some groups were encouraged to think of a creature that evolved to suit the life on this planet, the living area of this creature and the daily life objects it uses. The planet could be designed for a parallel universe, an imaginary universe, a universe from a specific source. To design the planet, some instructions were suggested, but students were free to follow other steps as long as they could prove its consistency and relation to wool. They were also free to focus on any of the elements, such as only the planet, or the creature. As an addition, students were recommended not to focus on the shape of their planet, instead to reflect on the story, characteristics, layers and its relation to wool. Some inspiration sources from cartoons and fiction movies were included in the workshop briefs. For the presentation, it was left open-ended on purpose, to allow the students to come up with their stories first. The results of the workshop consisted of dystopic and utopic scenarios, with many different approaches to wool material. Some example results are shown below,

Figure 1. Student works and presentation for a wool-based life form, Versheet

"After 3000 years, the world has been ruined because of climate change and there is no atmosphere. Because of lack of atmosphere, temperature difference is huge and there cannot be any creature existing, except jellyfish. Jellyfish has succeeded to survive and evolve. Their feet are able to climb everywhere, and they no longer live in the water. Also, they have kind of hands that allow them to cut the plants and live their daily life. Jellyfish can only eat the plant that they grow in the cave and when they eat the wool stays in Jellyfish's body. As a result, jellyfish die slowly because of wool." (Sidar, Sedef, Kibar, Vedat)

Figure 2. Student works for a wool-based life form, Planut

"After a huge explosion of wool, a new planet came and it was Called Planut. The Planet is donut-shaped planet made of wool. Half of the Planut is day and the other half is night. One year in our planet is 24hr in Planut. The creatures are called Bawools. Every sunrise a mountain of tiny Bawools are born.

They grow by rolling around their Planut. Bawools are making their houses by themselves by turning around themselves. Bawools feed themselves in the rivers also to get health from rivers. To have some fun Bawools love to roll from higher places like the mountains. If Bawools get crashed into the trees, they need to go to the river to get well soon. At night when a Bawool become really big, it explodes every morning to give birth to many tiny Bawools." (Seda, Samirah, Tolga).

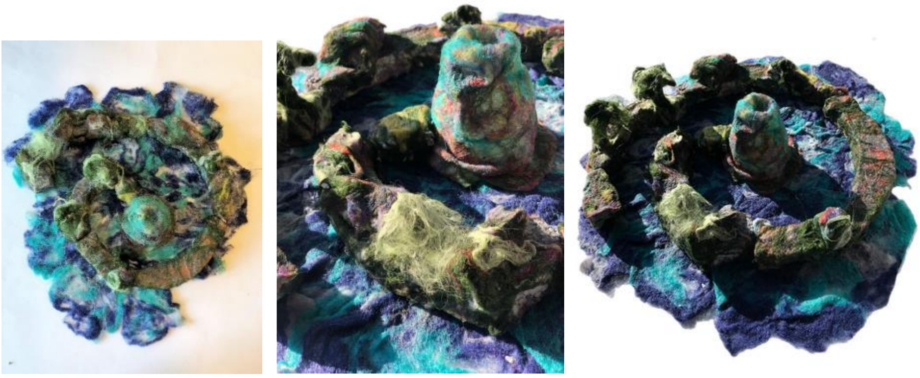

Figure 3. Student works for a wool-based life form, Wooland

"The land what had been separated by earthquake and had been exposed to mutation become a completely wool-based spiral island. The formation of the island is not fully completed, the creatures that exist on the island are moving and continue to grow. That's why, spiral island also constantly grows. As this spiral structure continues to grow, it will be a danger to the world. It will harm the plants and animals in the world and will completely disrupt the balance of the world. Because the world and living things in the world do not have any advanced features for living in a wool-based environment" (Asya, Berivan, Irem Nur)

As a result of the workshop, a final jury and exhibition was set in the faculty in August 2019; and afterwards, students were asked to evaluate the course in an anonymous form. As this was a part of the internship course, the grading system was as a pass or fail and contributed to gaining 2 ECTS credits. As the workshop was not graded and the evaluation took place after the students learned that all attendees who participated had successfully passed the workshop, the instructor believes that the answers reflect student's opinions and criticisms. In some ways, the workshop functioned similar to a traditional design course, asking students to expand their ideas and develop their designs along the way. A student commented "*The workshop was more enjoyable than I had expected. We had the opportunity to turn what we wanted / imagined into reality. Every day we presented the things we do regularly, so that our ideas change and expand with what we listen and tell."*

Some students stated they would continue experimenting with wool material and felt making method and that it allowed them to discover their creative identity, while some of them reflected on the difficulties of working with wool; *"Wool was not an open material to manipulate it and create. But by using other materials with it helps us to do what we couldn't do with only wool."* Also, some students had difficulties with the speculative aspects of the workshop especially at the beginning. One student wrote *"I had difficulty at first because there was always a right because of my previous training, we had the opportunity to be completely free with our imagination in this workshop, which is something we are not used to. In design, I became aware of the effect of material on the design field, on existing living inanimate beings. Besides, I worked with a different material and I'm quite satisfied, I do some experiments at home."*

Another aspect of the workshop was to challenge the relational outcomes and the designerly thinking process, by asking students how their final designs relate to their wool-based life forms. For instance, the character and its daily life objects they designed had to be consistent with the planet they created. A student reflected on the issue as follows: *"Unlike the planet we live in, our planet consisted entirely of wool. So, at some point, I had difficulty. For example, as the trees on the planet will be made of wool, anything that will be made of wood must be made of wool. In order for the living creature to survive, it must have certain characteristics that are related to the creature's body or internal system. And also, creature's daily life object had to be made of wool."* This feedback was coherent with the workshop aims, as it intended to challenge student's way of thinking about materials and also about the world.

In general, the workshop achieved the expected outcome, to introduce students to speculative thinking and reflecting on a material from different ways. While wool was a familiar material from everyday life, none of the students had previous experience on felting as a method, or working with it in design projects, and starting with this workshop led them to find creative and mind-opening ways to engage with the wool material.

5 CONCLUSIONS

As current design discourse assumes a separation between humans and nature, design education is primarily focused on human-centred and Eurocentric methods. To challenge this in design, intruders that bring in posthuman theories such as more-than-human, nonhuman or decentralizing approaches are needed [18]. Design from post-Anthropocentric discourses is being discussed more thoroughly in recent years, for instance through material-thinking, making-with or decolonial approaches [16, 18, 19]. The expanded definitions of design, which bring up nonhuman entities (such as materials and the environment) and challenges the anthropocentric assumptions could potentially involve more ethical practices, which foster symbiotic relationships between humans and nature. Accordingly, it is argued that further steps may be necessary to involve post-anthropocentric approaches in design education and study programs. As design operates within the broader systems, such as the ecological and social ones, design education should be considering how to approach these systems and contribute to the changing worldviews on how to coexist with nature and nonhuman entities. By acknowledging these, design educators could put forward values that go beyond consumerism and economic development ideas. The workshop presented in this study aims to expand the material agency part. These examples could be furthered by thinking of other materials, other nonhuman entities or other perspectives that involve post-Anthropocentric discourses in design and education.

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NEW AUTOMOTIVE AND AERONAUTICAL MODELS AND DESIGN OF DIGITAL TWINS TO SUPPORT LEARNING IN TEC21 EDUCATIONAL MODEL

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ABSTRACT
One of the takeaways from distance learning during the COVID-19 lockdown was that virtual labs and mixed-reality lessons needed to be attractively designed. The MxRP simulator based on replicating processes of an ERP system of a virtual car assembly company, models based on Meccano, were used. Surveys were carried out with students and teachers to improve virtual and augmented reality practices. As a strategy to bring the lessons to the intramural education of the Tecnologico, or Academic Extension, models of their own cars and planes were designed to take advantage of our student's creativity. The prototypes of these models will be built by 3D printing and machining through a magnet-based clamping model to replicate the same experience in both augmented and virtual reality of the assemblies. New and models previously built by our students for automotive and aeronautical competitions will be also digitized, creating digital twins for learning. The paper shows the context, planning of process of design, prototyping, and construction of these models, with the help of students and professors of the research group. The collaboration of schools of Industrial Design, Industrial Engineering, Mechanics, and Mechatronics for creating and manufacturing these models. Technological advances lead us to replicate professions through virtual and augmented reality, as well as the creation of digital twins to increase the quality, efficiency, and manufacturing of a product.

Keywords: Digital twins, professional education, higher education, educational innovation

1 INTRODUCTION

The application of virtual and augmented reality in education has had a great boom in recent years. These new technologies have gradually displaced traditional methods [1]. But the use of these technologies does not guarantee the attention of the students. The support of didactic techniques such as gamification should be considered, to be better accepted by the new generations of students [2].
On the other hand, the use of digital twins (digital replicas of physical models) allows for a richer learning experience and with the benefits that each of these types of models and their respective means of implementation. Digital models have the ease of manipulation without the fear of wear, damage, even breaking, this through immersive and safe means. The possibility of repetition and flexibility in times that VR offers are interesting characteristics to consider. All the above makes virtual reality a widely used medium in educational and entertainment environments [3]. For their part, physical models allow the use of more senses in the learning experience, a better understanding of proportions and characteristics of the object of study, among others. It is important to mention that both physical and virtual media complement each other and allow for a better and richer learning experience in groups of students with different cognitive abilities. As already mentioned, initially models built with Meccano were used for the virtual assembly plant [4]. In Figure 1 we can see an example of a Formula 1 vehicle made with Meccano and its digital twin, to be used in the virtual assembly factory. Due to the need to

request permits and pay for licenses for the use of commercial models, in addition to considering business models in the future, we intend to develop our own automotive and aeronautical models.

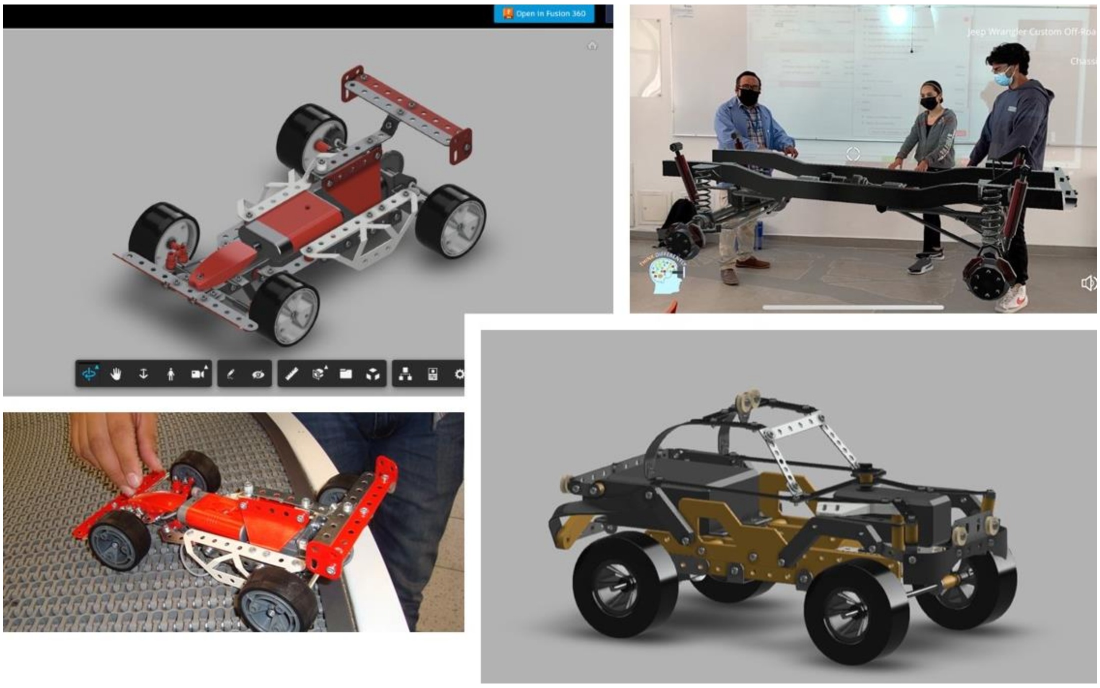

Figure 1. Formula 1 and Jeep car model built with Meccano and its digital twin

2 METHODOLOGIES

Before explaining the methodology behind this project, it is important to mention that this educational innovation proposal is supported by the Novus Fund for Educational Innovation. Novus is an initiative of the Institute for the Future of Education that seeks to reinforce the culture of evidence-based educational innovation among the professors of the Tecnológico de Monterrey, Mexico [5]. The main components of this proposal are described below, including the objectives, main deliverables, execution times, among others.

2.1 General aspects

The official name of the proposal is "Tec Assembly 21 Virtual design and scale construction of automotive and aeronautical concepts". The proposed thematic line is Preparation for the future and the duration of the project is 16 months (since February 2023 to June 2024).
On the other hand, the educational technology that is proposed is Mixed Reality, due to the possibility of considering physical and virtual models in the learning experience. In addition, it is considered that the most appropriate instructional strategy for the implementation of these resources should be Gamification. The academic level for its implementation is Bachelor, with second- and third-year students of Industrial Engineering and Product Design.

2.2 Educational innovation proposal

The educational need can be defined as follows: In the courses that have been determined, from the academic programmes of Product Design and Industrial Engineering, being able to see complete ERP processes run in laboratories or with the training partner (company). it is not entirely possible. This is due to the ability of laboratories and companies to receive visits from students (maximum 20), so emulating these processes in simulators with virtual and physical reality at scale allows us to have active learning by being able to manipulate parts and subsystems. and not a liability with only the explanation of the training partner.
On the other hand, the traditional way to develop skills is through laboratories (mini assembly lines), physical projects (models), video analysis and visits to industrial factories. Figure 2 shows examples of car assembly activities with Meccano.

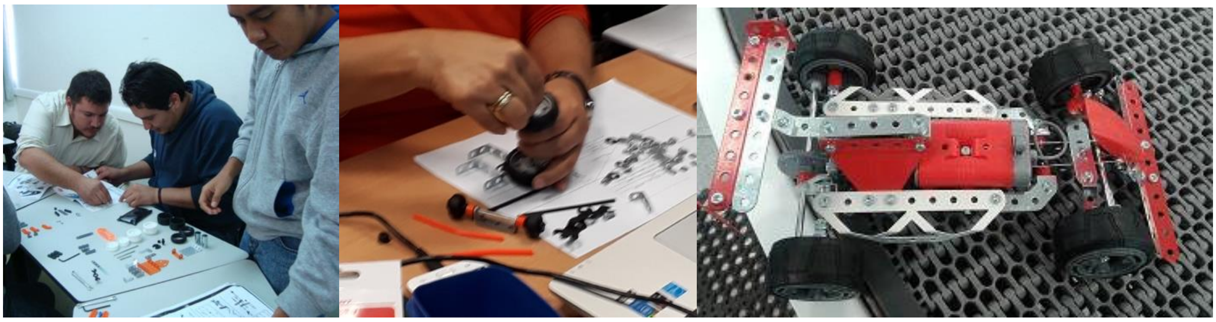

Figure 2. Examples of car assembly activities with Meccano

Based on the above, the general objective of the proposal is defined as developing virtual and physical educational models for the Tec21 virtual car assembly plant and a table game (board) for the development of skills related to the integration of systems and technologies. emerging in students of Industrial Engineering and Product Design. It is important to mention that the cars and planes will be integrated into a new virtual reality platform, project that started last year and will soon be ready for implementation.

It is considered that the innovation proposal, for its part, has the potential to be transferable since it could be implemented in other disciplines and/or levels, since it is the application of virtual/physical reality to recreate environments and dynamics that are impossible to live in the classroom, and even in visits to industrial plants. Although the initial proposal has a focus on Industrial Engineering and Product Design, due to the flexibility in terms of the focus of the activity, it may have applications in other careers such as Robotics and Digital Systems Engineering, Mechatronics Engineering, Mechanical Engineering, among others. It could also be used by graduate students in Engineering.

2.3 Administrative aspects

For the realization of this project there is a budget of $9,500 USD. This amount of money will be used for the payment of a product design student as On Campus Intern, for the development of models and manufacture of scale models. Also, for the purchase of materials for the manufacture of physical models, such as consumables for 3D printing, glues, paint, magnets, among others.

It is important to clarify that the team of teachers involved will not perceive any workload for carrying out the project. Only the On Campus Intern student will receive a monthly payment of USD 250 for each of the 12 months of work (four months per semester).

2.4 Justification of proposal

Because this proposal is an extension/expansion of two previous projects, related to virtual reality [6], augmented and physical reality [4], the educational technologies of 3D printing and mixed reality are the most convenient for the development of this innovation [7]. Figure 3 shows the initial design of the student interface of virtual assembly factory.

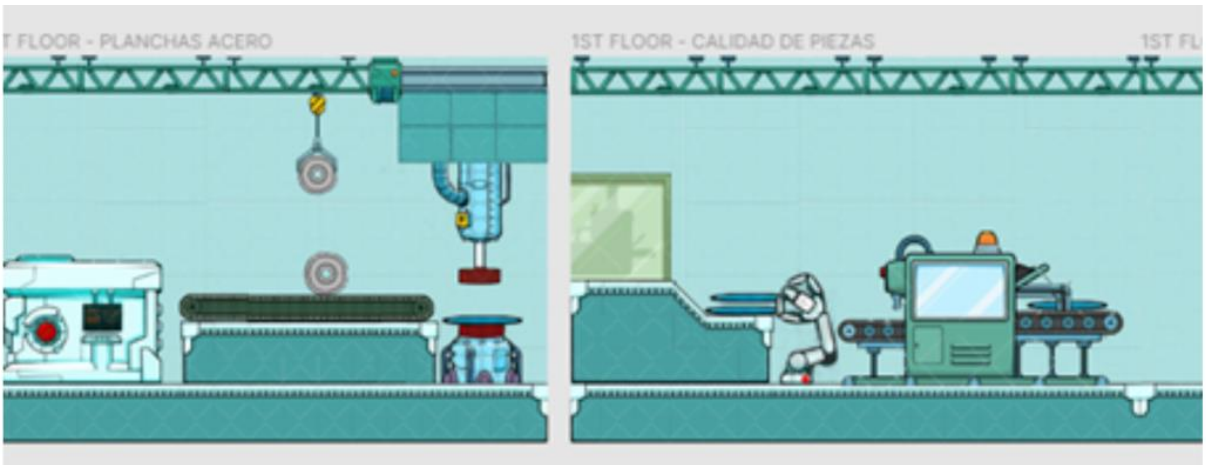

Figure 3. Initial design of the student interface of virtual assembly factory

Virtual and physical models of automotive and aeronautical concepts developed by the Institution are required in order not to depend on existing concepts patented by brands such as LEGO [8], [9], and Meccano [10].
The variables under study, for their part, are learning and problem solving, which to statistically demonstrate results, tests will be applied for the learning variable and the use of a rubric to identify development in problem solving.
Two knowledge exams focused on the practice (topic) of which we want to measure the use will be applied. The first prior to the automotive and aerospace design, the second after having carried out the design practice, to measure if there is learning and that it is statistically significant.
The hypothesis to be verified is the mean of the average of the qualifications obtained in the exams, which for the study will be called "knowledge gain"" is different between the two, being M1 before the PV and M2 after applying the PV, this is we can do by analysing the individual grades of M1 vs. M2 using a two-sample student's t-test in which we want to validate not only that they are different, but also that the mean of M2 is much higher.
For each subject, a specific practice of the virtual plant will be designed where the elements of the test (exam) are linked so that the student has a more detailed knowledge of each element and can, through experimentation, associate the theory in class with the practice offered by using the virtual plant [11], [12].
In the gamification aspect, we found that, in 2021, 70% of teachers saw an increase in student participation when using educational video games. Games, in any form, increase motivation through engagement. Nowhere is this more important than in education [13]. Other studies have found that gamified learning interventions have a positive impact on student learning, however, the impact of gamified learning interventions on student engagement varies depending on whether the student is motivated [14]. These data are relevant to our proposal as it is considered to impact a variety of disciplines and concentrations where student engagement can be increased and learning improved.
Finally, we believe that developing our own aeronautical automotive concepts (virtual and physical) will be a great contribution of added value because we will not depend on licenses and permits from companies such as Lego and Meccano. This will allow us to scale the proposal as required (continuing education) and at a given time (why not) consider marketing it. Another advantage is that these concepts will be adapted to the virtual Assembler and with the required specifications and scope.

2.5 General implementation proposal

The general implementation proposal, as already mentioned above, will consider from the months of February 2023 to June 2024, but considering only the academic periods included in that determined time. That is, the project will be carried out within the semesters February-June 2023, August-December 2023 and February-June 2024. The intensive periods of summer 2023 (July) and winter 2024 (January) will not be considered. This responds to the workloads of the teachers and students involved.
Figure 4 shows the most important aspects of the project and its distribution in the three semesters considered.

Figure 4. Initial design of the student interface of virtual assembly factory

As can be seen in Figure 4, the first semester will be used for preliminary research regarding which design parameters, components and systems, and production line that will be considered for the project. It is expected to achieve the design, 3D modeling and physical manufacturing of at least two cars and two small aircraft. The intention of the first semester is to obtain the first car design. It will be an MCC (Micro Compact Car), due to the simplicity of its design.

Until the moment of writing this work, progress has been made in the recruitment of the second year student of Product Design who will serve as On Campus Intern; in the investigation of the components and systems to be considered in each type of car and airplane and the different types of assembly lines; as well as in the definition of the parameters to be considered for the design, manufacture and assembly of the models.

The second semester, for its part, will be used for the design of the two aeronautical models and the missing car, the incorporation of 3D models to the new virtual reality platform and the first implementation tests (this new VR platform is still under construction and is expected to be finished by April 2023). Regarding the gamification strategy, which is an important component of the complete learning experience, it will be defined based on previous experiences [2].

Finally, in the third semester, the activities will be carried out in different courses of Industrial Engineering and Product Design, the collection of qualitative and quantitative data, as well as the documentation and closure of the entire project. Publication of results in indexed journals and conference papers is also considered.

2.6 AI implementation in the creative process

In order not to occupy an existing design, teachers and students created our own automotive concept design, to work with the virtual assembly machine. Based on the Double Diamond Model of the British Design Council [15], this divergent process incorporates artificial intelligence in the generation of alternatives for the design of a two-seater car under the "microcar" segment, its two immediate references being the Renault Twizy and the Smart ForTwo. The model is graphically based on a simple diagram that depicts the divergent and convergent stages of the design process, giving the model the shape of a double diamond. The model is also called the 4D model because the name of each phase begins with a 'D': Discover, Define, Develop, and Deliver.

The way in which this principle is adapted to the development of the conceptual proposal of automotive design, lies in implementing artificial intelligence in the "Develop" phase. The discovery phase is given by the purpose of the investigation that corresponds to emulating the process of an assembly company in a virtual way. After an initial formal exploration through photos and sketches and once the automotive segment (Microcar) has been defined, we proceed to the Develop phase, where artificial intelligence is "fed" through “prompts” to generate a greater number of iterations in the process. as little time as possible, exploring the different alternatives that the algorithm produces than two different Artificial Intelligences: Midjourney and Deep Dream Generator. Before converging in the Delivery phase, the proposals are reviewed to obtain feedback from the design team, and thus, be able to determine a proposal that combines the requirements and appropriate parameters of the brief proposed in the first phase (Figure 5).

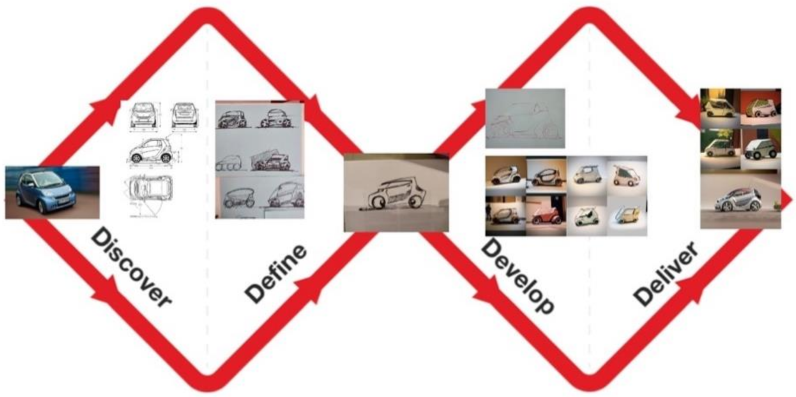

Figure 5. AI assisted double diamond model

3 CONCLUSIONS

Due to the timing of the project, there are currently no concrete results, but the authors consider it important to carry out this work to share the background, context, and implementation process of this educational innovation, to be developed at the Tecnologico de Monterrey Campus Queretaro. And precisely the Tecnologico de Monterrey, as a private system of universities in Mexico, is recognized as a pioneer in educational innovation in Latin America. The expectations we have, and based on similar experiences, is that the implementation of these new automotive and aeronautical models of our own will be well accepted by the Industrial Engineering and Product Design student population and will contribute to a better hybrid learning experience (digital and physical), with the support of virtual reality and the ingredient of gamification. It is also intended, as already mentioned, to eventually to share with others Campus of our university and commercialize the virtual assembly platform and the automotive and aeronautical models. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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MINOR DEGREE IN REGENERATIVE DESIGN. A NEW DESIGN EDUCATION PARADIGM IN MEXICO

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ABSTRACT
A new narrative and approach to address the unprecedented challenges faced by society on a global scale is urgently needed. The concept of sustainability is deemed inadequate, and a shift towards regenerative design and development processes is proposed. Regenerative Design (RD) is presented as a systemic and ecological action that seeks to co-evolve with nature and reverse the degeneration of the earth's natural systems. The article proposes a new interdisciplinary engineering and design education programme from a regenerative approach at Tecnologico de Monterrey, which involves community participation, ethnographic tools, and design charrettes. The programme, in a minor degree format, aims to co-design human structures and systems that can co-evolve with living systems, value the relationship between human systems and the natural ecosystem, and create positive and abundant futures. Success cases are presented to exemplify the application of the methodology.

Keywords: Regenerative development, sustainability, regenerative learning, higher education, living systems

1 INTRODUCTION: PERTINENCE OF REGENERATIVE DESIGN IN HIGHER EDUCATION

The planetary-scale socio-ecological and climate crisis is related to a social injustice and a biodiversity loss [1, 2]. A fundamental rethinking of the way we develop territories, cities, and communities is needed. Also is needed a transition towards futures in which eco-social systems are designed to balance anthropogenic activity and the integrity of natural ecosystems [3, 4]. While sustainability promises not to affect future humanity, it does not contemplate the possibility of co-evolving with nature; It is no longer enough [5]. To restore human presence on Earth, we need to move towards regenerative sustainability [6, 7], which is aimed to heal our damaged world, allowing it to evolve and thrive [8,9]. It is needed to create a positive future through a worldview based on living systems [10]. With the 21st century comes a new paradigm of regenerative development and design [11], based on the understanding of the patterns of functioning of living systems, their uniqueness of each place, its essence, vocation, and potential, to design processes that help to affiliate us with nature, learning from it, collaborating in its restoration, reconciling with it and proposing a development based on "being nature".

Facing the socio-ecological crisis, it is paramount to strengthen knowledge and awareness in order to reduce or reverse its effects [12]. In this context, universities have the potential and responsibility to facilitate change. Signs of a transition towards regenerative approaches [27], circular society [14, 15], renewable energy-driven society [16], sustainable food production [17] and well-being [18] have been implemented. Learning and education have an important role as a catalyst of such transitions [19].

In the face of these new learning paradigms, this must include an epistemological review of education approaches themselves [20], including a rethinking and re-signification of educational structures, practices and policies inspired by a regenerative approach [3].

Regenerative learning in higher education aims to connect university education to the challenges of transition in ways that support personal and planetary health [21, 22] and to redirect and redesign transgressive systems within socio-ecological boundaries [23] highlighting leverage points and spaces within higher education where systemic change towards regenerative sustainability can take place [24]. Regenerative learning is based on an ecological approach that connects to transitions towards sustainability at the local level and helps prepare students to navigate current complexities and

uncertainties, contributing to a better and possible future, with a clear moral responsibility to contribute to healing human relationships with each other and within the living system [25, 26].
In this paper, it is presented the basis and methodological framework of the *Minor Degree in Regenerative Design* which, from an interdisciplinary approach, is implemented at the Tecnologico de Monterrey (TEC), and the reflection on the results of its first two editions.

2 CONCENTRATION AS MINOR DEGREE MODEL

In recent years TEC has been transforming and breaking boundaries in innovative education. With the Tec21 new educational model, TEC intends to activate and potentiate innovation capabilities. Likewise, it allows students to choose a path and make their graduate profile unique, seeking to make them more competitive and with more skills to face world´s challenges. Each bachelor's degree of the model has three stages (entry, focus and specialization) and from the first semester they experience training units based on challenges, which have the objective of developing competencies which integrate knowledge, skills, attitudes and values [28]. Within the area of specialization of the School of Architecture, Art and Design, a series of semesters for the 4rth year were designed with a Minor Degree format, projected as a concentration, which means that is an exclusive and 100% dedication by the student with any other subject to take. With this format, students strengthen and develop their skills through experiential learning experiences and solving a challenge together with companies and/or organizations.
In the Minor Degree in Regenerative Design (MDRD), as a distinctive, an interdisciplinary approach is encouraged through the participation of different experts as teachers or training partner or partners (company, NGO organization or government institution). The expertise of teachers includes architecture, design, biology, geography, anthropology, civil engineering, education science, urban planning, among others who are sensitive to the search for regenerative development and are transcendentalists in their disciplines. This MDRD is offered to students who are in the sixth or seventh semester of degrees in architecture, urban planning, design, civil engineering and sustainable development engineering.

2.1 Competences acquired

The Tec21 model also integrates a skills assessment scheme. These can be transversal, referring to the different courses, and disciplinary competencies, referring to the fact that they enhance the degree that they have chosen. For this MDRD, the student must acquire the following competencies: As Transversal competences, a) Ethical and citizen commitment, and b) Citizen commitment for social transformation. As disciplinary competences also were acquired c) Design and d) Systemic, prospective and participatory approach, e) Urban culture and environment and f) Regeneration strategies and g) Design of new avenues of innovation and h) Regenerative design itself.
In addition to the official evaluation of the development of the competencies listed above, and the feedback officially received on their experience in the Minor Degree, some particular surveys are designed and carried out at the beginning and at the end of the semester, specifically designed to assess both the experience that the students have students, such as their learning process, their acquisition of knowledge around the idea of regenerative development and design as well as the development of pro-environmental awareness and beliefs.

3 STRUCTURING THE COURSE

The course is developed through 17 intensive weeks focused on solving a challenge through answering the question: how can we potentiate the vitality of a specific site through regenerative processes? Therefore, the students will develop regenerative design proposals, such as processes, products, services, architecture, or landscapes. Always in collaboration with a community linked to an emerging natural, social, and cultural landscape. The aim is to reveal, through the potential and the vocation of place, the vital support for a better, possible, resilient, regenerative, fair and equitable future. The challenge is developed in a collaborative way, from the re-signification and recognition of the designer's own role, which evolves and adapts to the circumstances of place. The semester unfolds through an evolution of knowledge, feelings and experiences which aim to develop in students, teachers and the community a change of mindset as a deeper consciousness of the role of nature and each individual in the larger system. The curricula integrates a set of strategic tasks under the principles of regenerative design, in co-creation with a community and different stakeholders involved.

3.1 Challenge stages

- ***Stage 1: Recognition of one, with the community and with place.*** Within this stage, the resignification of oneself is sought, as a person and designer, with nature.
- ***Stage 2: Regenerative Co-design and prototypin*g**. Stage where benefits obtained from collective decisions are identified.
- ***Stage 3: Proposal, future plan and co-evaluation***. Stage where a regenerative strategy is ensured in the applied design.

Since the stages of the process are not linear, they are constantly retaken and fed back to advance to the next stage. The upward spiral diagram represents the way the process is evolving or when needed, going back to the previous stage in order to feed the final proposal. (See figure 1).

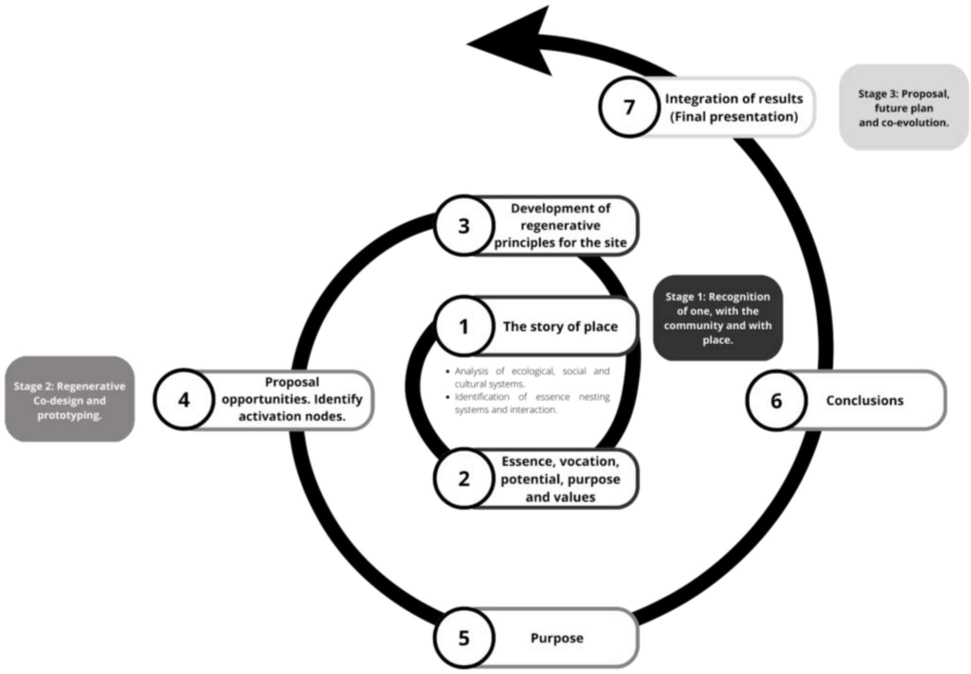

Figure 1. Challenge Stages. Credit: Carlos Cobreros

In the first stage, the student becomes aware of its role within the system through a deep understanding of "place" by understanding the ecological, cultural and social structure within the nested systems. As something distinctive in MDRD, in this stage, it is very important to reinforce the idea that we are nature, that we design being nature, for which there is a specific module, with specific activities for it.

Place is defined as the multilayered network of living systems within a geographic region that results from the complex interactions, over time, of ecological (climate, geology, soil, vegetation, water, wildlife, etc.) and cultural systems (distinctive customs, expressions of values, economic activities, forms of association, ideas for education, traditions, etc.). The regenerative paradigm affirms that development can and should contribute to the capacity of all the natural, cultural and economic systems that occur in a place to grow and evolve their health and continued viability [29]. The methodology applied for this regenerative understanding of place (living systems, including human systems), is based upon research, participatory processes supported using ethnographic tools and design charrettes. By answering the questions: how big is this place? and who is this place?, in this first stage the uniqueness of the place and its essence are revealed in order to take the next step in the design process.

The second stage will be focused on recognizing the potential and vocation by answering Who will this place be? and How will it evolve?. The next step will be to identify the nodal interventions. These are strategic interventions that can contribute to the evolution of the system. According to the regenerative principles these projects target the points of highest and most systemic return—similar to how in acupuncture, a set of points are recognized as most effective for achieving systemic regeneration. The findings are shared with the community to have their approval and consensus to continue developing the prototypes and co-design with the community.

The third stage focuses on the development of the whole proposal, conclusions and documentation. Finally, the results are shared with the community and stakeholders creating a field of positive engagement among different stakeholders that can contribute with the specific projects.

4 COURSE DEVELOPMENT: FIRST TWO EDITIONS

4.1 Edition 1: Campus Vivo

The first time this course was taught, it focused on developing the project together with a local training partner familiar to the students. In this case it was their own community, TEC - Campus Querétaro, which is located in the city of Querétaro, Mexico. The administrative office of the campus acted as training partner and to whom the finished project was presented. The campus is located in the north-central part of the city with an extension of 13 hectares. The university district, where it is located, has parks, shopping centres and different types of housing. Likewise, the campus integrates 14 buildings, sports fields, parking lots, green areas and a small "canal" that works as a rainwater collector. For the development of the project, the students had the task of understanding the “place” through the phases of the course and the challenge identified.

On this first occasion, 13 architecture and design students participated, which were subdivided into teams that focused on different areas of the campus. Teams are formed by affinity between peers or by topics of interest. Campus Vivo project resulted in a master plan and in three main interventions: 1) *A-Puente,* a concept that features an experiential path aimed to eradicate the fragmented space re-signifying “water as bridge and generator of life” and potentiate and diversify campus infrastructure into an opportunity to manage water positively. (See Figure 2); 2) *Living Future Lab and Ethnobotanical Garden*, a regenerative learning area within the campus featuring classrooms, a museum space, a plant conservatory, and parking lots surrounded by an ethnobotanical garden with the capacity to host, conserve, and integrate native plants as an edible forest; 3) *Parque Flux*, An open space for coexistence both interpersonally and with nature. In this way, connections between the campus and the city would be generated, becoming a point of exchange of knowledge and biodiversity.

Figure 2. A-Puente and Women's plot concepts. Credit:CDR students cohorts

4.2 Edition 2: Juanacatlán Regenerativo

For the second edition of the concentration, the venue chosen was the community of Juanacatlán, located in the municipality of Tapalpa in the state of Jalisco, Mexico. The training partners were Tapalpa Municipality Administration, Rainforest Alliance and Juanacatlán Delegate Office. The community of Juanacatlán is located in the temperate mountains between the towns of Tapalpa, Atemajac de Brizuela and Chiquilistlán. This community of approximately 4,000 inhabitants depends on agriculture (corn and berries), forestry and tourism. For the development of the project, the students had the task of visiting Tapalpa at different times according to the phases of the course and the challenges encountered with the help of the training partners. Ten students from the architecture and design careers participated, which were subdivided into four teams. In this case the teams were formed also by affinity between peers or by topics of interest: water, forest, women and tourism.

The “Juanacatlán Regenerativo” project resulted in the following interventions: 1) *Water as living system,* a proposal to improve, manage and value water use. It integrates various systems to cultivate, zone and circulate water. A series of natural springs and streams are identified as gathering spaces but also as enhanced functional spaces that prevent floods and distribute water around the community; 2) ***Tourism and identity***, a proposal aimed to highlight the main attractions of the village and improve its identity. Several walking trails, monuments, rural image identity and an environmental pedagogic space are interconnected, guiding the visitor to appreciate and maintain continuous regeneration; ***Women cooperation and wellbeing***, a space for women, where they can participate in caring for its community and personal well-being. The place is adapted for cultivation activities, work with medicinal plants and organizing cultural and training activities, such as physical exercise, art, gastronomy and trade. It includes a plot where an equipped classroom, outdoor gathering spaces and allotments (See figure 2); ***Living Forest Museum***, An open space in which the community is acknowledged for its way of herbalism, forest management and collection of native vegetation. An educational corridor and nursery are displayed as strategies to regenerate their natural resources.

5 DISCUSSION AND CONCLUSIONS

The incorporation of this new way of learning focused on regeneration at TEC, provided an opportunity to focus beyond the mechanistic approach to a more ecological and systemic approach. The model of MDRD undertaken by students in one semester, as a unique course, manifested a solid involvement in what matters most, which is to seek for a living and healthy planet. It was thanks to the participation of a team of teachers with an interdisciplinary scope that the course was carried out successfully. Although the first edition was somewhat experimental, the expertise of the teachers was expanded for the second edition. All the proposals generated a set of actions, services, experiences, architecture and products design that value the relationship between the human system and the living and natural ecosystem.

The proposed competencies are developed by the students, and through the surveys that were carried out in both editions, could be known that the students obtained a very positive experience of change and that the main aspects and principles of regenerative development and design were acquired and deepened. It was also obtained that the connectivity and bond with nature increased and with it a greater feeling of belonging, of being part of nature itself, as well as that a greater environmental awareness was developed. Serving vulnerable communities, linking with the training partner and delivering good results to the community were achieved. Finally, gratitude, abundance, ecological balance and mindset change are sought in the pedagogy of this MDRD and are aspects that break with current paradigms. Since learning and education have an important role as catalyst for regenerative cultures transitions, this MDRD seeks to change some of the current teaching and learning paradigms through promoting ecological and systemic thinking instead of linear thinking. Through a deep nature immersion to achieve a change of mindset in the emotional and intuitive level, and not only focusing on intellectual and practical abilities, focusing on the narrative of place instead of a rational diagnosis of the site, by focusing on potentials rather than problems and the engagement with a community to develop capacities and not welfarism.

Currently the third edition is being developed and the teaching processes and new implementations that continue to be documented will continue to be investigated.

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STUDENT AGENCY - A DIFFERENT PARADIGM FOR LEARNING

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ABSTRACT
Sustainability transitions are not hindered by technological barriers but above all by the lack of well-qualified people. Educating the next generation of engineers and product designers is therefore more important than ever. However, a traditional widely used model of instruction and evaluation is not sufficient to prepare this next generation for the demands of society. It is appropriate that curricula should be adapted. If necessary, in a disruptive way. The question was how to develop an education module in which students are agents in their learning. In which students decide what and how they will learn, and in which they can prepare for a role in society that is in shock. To propel them in a new direction a disruptive education innovation has been designed and tested. This new method turns the traditional education model upside down. Students and lecturers are transformed in equal partners in an innovation consultancy firm with a passion for engineering, product design, and with a focus on sustainability transition. Students explore their emotionally intrinsic values that enables them to accomplish great things, to experience meaning in their lives and work, and leads to a significant learning experience.
Purpose of this paper is to give individuals and organisations involved in higher education insight into a new method of education based on new values such as student agency, equal partnership, partnership learning communities, significant learning experience, and the strong belief students have the capacity and the willingness to positively influence their own lives and environment.

Keywords: Education innovation, student agency, equal partnership, co-agency, significant learning experience

1 INTRODUCTION

This study describes the unfolding of a particular case within a real-world context namely a disruptive education (service) innovation at Department of Engineering at Technical Faculty of Amsterdam University of Applied Sciences (The Netherlands). During their graduating year EPD students can participate in a future excellent programme (10ECTS). In the three years prior to the graduation year, they literally ‘followed’ the educational programme. It was high time to design a module that would give the students the opportunity to take the initiative themselves, to choose their own direction, to be responsible for the programme, the results and, above all, to discover where their possibilities are. The next generation of engineers are of paramount importance in finding solutions to problems and designing sustainable and responsible innovations shaped as much by environmental, social, and economic measures, as enabled by technology [1]. It is our duty to prepare them as well as possible for reality in society and thus the grand challenges facing people and nature. Over the past decade, there has been increasing attention to the need to adapt the education system to the demands of the increasingly complex and rapidly changing world [1] [2] [3]. The climate catastrophe and the exhaustion of the earth are two life-threatening problems for humanity. Global co-habitation is at risk because in the context of ecological systems, coexistence between humans and between humans and nature is under constant pressure. To propel students and lecturers in a new direction a disruptive education innovation has been designed and tested. The idea is quite simple: students and lecturers are transformed in equal partners in an innovation consultancy firm with a passion for engineering and product design, and with a focus on sustainability transition. Students can explore their emotionally intrinsic values that enables them to accomplish great things and to experience meaning in their lives and work. A module in which students feel respected, appreciated, and acknowledged.

It turns the traditional education model upside down and leads to a significant learning experience for students as well as lecturers.

2 THE ORIGIN OF THE METHOD

At the end of their study Business Engineering, students could choose from three specializations namely *Process Optimization*, *Business Development*, and *Innovation Management*. Egbert-Jan van Dijck, the first author, was responsible for the development of the curriculum as coordinator of the specialization *Innovation Management*. It was his idea to let the students go through their own transition in the run-up to their graduation research. The new method was conceived and developed by the first author and further tested together with Maarten Meijer, the second author, in a new module *Innovation Design* as part of the study Industrial Design Engineering (IDE).

Inspired by publications on *student agency, equal partnership, co-agency* [1] [2], and *significant learning experiences* [4] this education innovation has come about. These new concepts turned out to be an excellent fit for previous work experience as a partner of an innovation agency.

Having and maintaining the right of organisations to exist requires adapting to the ever-changing world. In the period in which economic growth, market share, (economic) profit maximization was key, the emphasis within organisational innovation was on product- and process innovation. But in recent decades, the emphasis has increasingly shifted to sustainable or responsible innovation, and transformative innovation. When it comes to sustainability transitions, then there is even talk of system innovation at meso-level. Thus, it is important to be able to switch between the big picture (world and society) and the details (organisations, and their products and services) and back and forward.

2.1 Objective

The main goal of this education innovation was to develop an education module for students and lecturers in which students are agents in their learning. To decide what and how they will learn, and in which students can prepare for a role in society that is in shock. Every technical solution/design comes about in an increasingly complex and rapidly changing world. To come to a good solution as an engineer, students must be able to observe, interpret and include that changing environment in their solution/design. Otherwise, they will not create the solutions but the problems of tomorrow. They must learn to anticipate a changing world in which they increasingly have to consider the possible impact of their solution/design/innovation on other people and nature. Innovation in general is a process that can be carried out most successfully by a diversified cross-functional team. In all respects, the more diverse the better. It is therefore students from different specializations participate in this module. Thus, the module is open to students from other educational programmes within Engineering. This course builds within the specialization Industrial Design Engineering (*IDE*) on the courses *Value proposition design (VPD)* and *Product and Business (PB)*, but it is also accessible for students without this prior knowledge. The following chapters describe the unfolding of the education innovation in the *Innovation Design* course by merging the concepts of *Innovation management* with *product Design*.

3 THE NEW METHOD WITHIN THE 'INNOVATION DESIGN' COURSE

Through the six years the module has existed it has changed from 'Innovation Management', a specialization as part of Business Engineering, to 'Innovation Design' as part of the study Industrial Design Engineering. All the years we have kept the focus on student agency. The name of the course changed in 2019 after an organisational change has been implemented within the department Engineering.

3.1 From Problem in Context (I) to Expected Outcome (O)

The new method is the result of a design science research. The design propositions used follow the CIMO logic [5]. Due to the limitations of the scope of this article, it is not possible to write out the different design propositions. For this reason, an overview was chosen in which the (Problem in) context (C), the generic intervention (I), the generative mechanisms (M) and the expected outcome (O) are shown at three different levels. In the opinion of the authors, the newly developed method is an intervention that is both an appropriate solution to problem of the university (C2) and students (C3).

The generative mechanisms are obviously different for the university and the students. The desired outcomes are entirely in line for the university and the students (O). After all, the university wants to offer an education that successfully educates students to become the new generations who can create the future. The following is the description following the CIMO-logic per level:

- **Society level:** Sustainability transitions are hindered by the lack of well-qualified people (C1). Education needs to be adapted to provide well-qualified people now and, in the future (I1). Society stimulates higher education to ensure well-qualified professionals and the contribute to the betterment of a dynamic society through practice-based research and innovation (M1). Society will become more sustainable, and the world will be a better place for all human and non-human elements (O1).
- **University level:** Traditional widely used model of instruction and evaluation (Figure 1) is not sufficient to prepare the next generation engineers for the demands of society (C2). To develop an education module for students and lecturers in which students are agents in their learning, in which they can prepare for a role in society that is in shock (I2). Students and lecturers show greater motivation to work as co-agents and learn from each other (M2). A new educational student centric model (Figure 2) based on intergenerational cooperation (students and lecturers) is established to ensure a good alignment of interests, and the demands of an increasingly complex and rapidly changing world (O2).

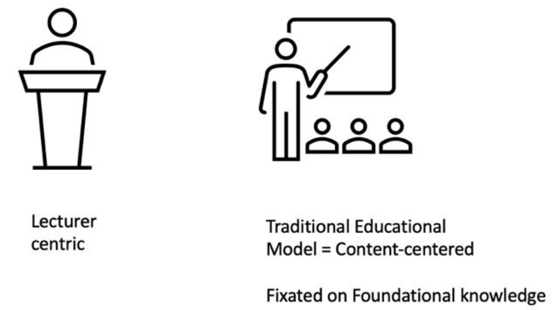

Figure 1. Traditional Educational Model

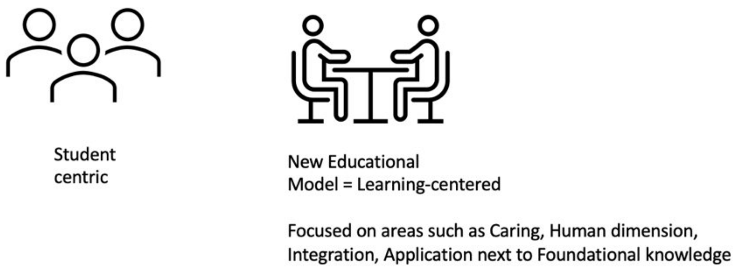

Figure 2. New Educational Model

- **Student level:** Students literally must 'follow' the educational programme, they are not empowered to play an active role in deciding what and how they will learn (C3). To develop an education module for students and lecturers in which students are agents in their learning, in which they can prepare for a role in society that is in shock (I3). Students tend to show greater motivation to learn and are more likely to define own objectives for their learning (M3). Students explore their emotionally intrinsic values, feel respected, appreciated, and acknowledged (M4). Students experience to a large extent the sense of responsibility (M5). Students have learned how to learn (O3). Authenticity of the students has been developed. They do things because they want to do them and not because it's expected of them (O4). They experienced how to orientate themselves on the major challenges facing the world and are more aware of the role they want to play (O5).

4 RESULTS

The innovation consultancy firm takes the form of a matrix organisation with expert teams and cross-functional project teams. Students and lecturers act as equal partners, and where possible as an expert and coach. In this paper, students/partners are referred to as students for the good understanding. Students first orientate themselves on the various societal challenges which have been appointed by the Dutch government [6]. These societal challenges are linked with the business community and knowledge institutions. This has resulted in 25 concrete Missions for the Future within four themes, namely (1) *Energy Transition and Sustainability, (2) Agriculture Water Food, (3) Health and Care, and (4) Safety*.

4.1 Organisation

The participants can follow their own interest and choose from the four themes and then from the underlying 25 Missions for the Future. After they have made their choice, they form expert teams with participants with the same interest. For example: a participant is interested in the theme *Health and Care* and wants to contribute to the Mission: "*By 2040, all Dutch people will live at least five years longer in good health and the health differences between the lowest and highest socio-economic groups will have decreased by 30%.".* This team of three or four partners can now specialize in this theme and the different missions. During the first phase, all partners are trained to use various methods and tools to carry out orientation at team level. Such as PEST-analysis, Scenario Planning, SWOT-analysis, and Business Model Generation. In this way they learn to look from the outside (macro and meso level) to the inside (micro level) and vice versa. As a result, lecturers and students are no longer content-centred and fixated on Foundational knowledge but learning-centred and focused on areas such as Caring, Human dimension, Integration, Application next to Foundational knowledge [5]. This promotes responsible design, and co-habitation.

Each team chooses a team leader every week, everyone has their turn one or more times. The team leader is responsible for ensuring that the team performs and delivers. Every week, team leaders together choose a 'managing partner' (or duo) from among their members who is responsible for the work in that week, good transfer to the successor managing partner and finally, the progress regarding the closing event. The managing partner can also make decisions about the entire consultancy firm.

Members of the different teams can also participate in cross functional project teams that are responsible for special activities such as 'developing corporate identity', 'designing and building the website', 'organizing closing events', etc. to successfully increase innovation, efficiency, and employee engagement in the firm.

Within the teams, we also expect substantive feedback on each other's individual behavior and results, the team results and collaboration, and on the performance of the consultancy firm as a whole.

4.2 Description of the stages

Below is a weekly description of the activities undertaken during the 10 weeks course 'Innovation Design'. Highlighted in blue is the activity of which the initiative lies with the lecturer/coach. Green marked are the activities of which the initiative lies with the students.

Table 1. Overview activities per week

	Week	Activity
	1	Kick-off by one of the committed lecturers (maximum 1 hour!)
	1	Immediately after this kick-off, the initiative is handed over to the students. Students and lecturers are transformed in equal partners in an innovation consultancy firm with a passion for engineering and product design, and with a focus on sustainability transition.
	1	Students organize themselves and kick start their innovation consultancy firm.
	1	Students organize themselves into cross-functional project teams to set up and execute projects to contribute to the office such as designing a corporate identity, logo, and plans for de design of a website, templates for presentations, videos, a closing event etc.
	2	Students orient themselves on the different themes and Missions for the Future appointed by the Dutch government.
	3	Students draw up a wish list of workshops and expert sessions to deepen their knowledge. Lecturers act as partners/experts in the field of Scenario Planning, and

		other methods and tools. They give workshops in this area, make materials available, and assist the other partners (students). This will be followed up in the other weeks.
	4	Based on their own interest, students choose a theme and a specific Mission for the Future. They investigate that theme and Mission, and they come up with 4 scenarios via 'scenario planning'. Students choose one scenario as a starting point for further research.
	5	The different teams work together to investigate the shared theme and Mission of the Future of their choice. This is in preparation for individual follow-up research.
	5	Teams submit their research report with a clear synthesis. These reports are peer-reviewed. The suggestions in the feedback are studied and reports are adjusted.
	6	Students hand in a 'teaser video' about their Mission of choice, scenario and what students will tell in their final video in week 9 for the event website. With that teaser video students will already approach people and organisations students want to invite to the closing event.
	7	Students will work out their own scenario, through more research and visualization, and create a storyboard for their final video. In addition, students work on their individual research report.
	8	Students submit their individual research report with a clear synthesis. The conclusion consists of a self-formulated concept graduation research proposal and a list of organisations that students will approach with that concept research proposal.
	9	Students work together on the last chores for the closing event.
	10	Closing event takes place, guests from the professional field and other interested parties are welcomed, students present their findings and proposals to their audience and the innovation consultancy firm is established.

4.3 Evaluation

Evidence from field testing is derived from the evaluations performed over different years among students and lecturers. Every year, the group of students and teachers unanimously appoints the enthusiasm that has led to 'electricity' in the entire project group. In the meantime, remarkable results have been achieved in the eyes of all those involved, and outsiders such as experts, guests, and fellow lecturers. Since the educational concept, the design of the curriculum, the learning objectives and the assessments for learning and the assessment of learning have changed radically, a comparison between the results of the 'traditional method' and the 'new method' is not possible.
The dissemination of knowledge is an important part of the module. This year it has taken the form of individual- and group presentations, workshops, videos, a YouTube channel with video's, a website, a publication of a book with the results by the students, and a closing event in which a very diverse group of guests participated. Final presentations of the outcomes of the groups at the closing events are always of a high level.

4.3.1 Issues worth mentioning

Responsibility and uncertainty: Students often mention that they never worked in such a large group before. Most students didn't find it easy to just take responsibility as managing partners of an office of 30 to 60 students. Especially in a new situation with a lot of uncertainty, and freedom to act. As one student put it: "*In the beginning there was a lot of uncertainty because we have all the freedom got to determine things".* Some lecturers find it difficult to let go of the traditional model. If they think that something is not going properly, they immediately intervene and correct students. This is at odds with the idea behind the new model in which the students themselves decide how they can act and experience learning moments. If it is really necessary, the lecturer can do suggestions for improvements as a coach.
Communication and planning: Immediately after the transfer of the initiative in the module by the lecturers, students discovered that communication is crucial. Another student said, "*Furthermore, I have my schedule skills improved by creating a clear schedule. With that planning, I was able to (along with other members of the planning committee) provide multiple individuals and groups with a clear guideline.*

With that directive, they were able to achieve their goals and it helped them to be sharp during the project without losing the common thread. So, I have in a sense developed two skills, namely my communication skills as well as me planning skills for a large group."

Big picture and the details: Most students have struggled to develop an understanding of the major challenges facing the world and the individual contribution they could make to sustainable sustainability. One of the students put it this way: *"In this course you learn to analyse a social problem and convert it into a design proposal, in which a large group of equals must also achieve a joint result.*

Responsible design: As a result, students are able to achieve balanced social, environmental, and economic development by embedding ethical decision-making in inclusive and sustainable design practice.

5 CONCLUSIONS

This paper posits that increased understanding of the role of student agency in engineering education, in particular in two different ways, has been established. Firstly, to accomplish the objective of this study, to develop an education module for students and lecturers in which students are agents in their learning, in which they can prepare for a role in society that is in shock. Secondly, during the problem exploration it was established that in order to contribute to the solution to problems on three different levels, student agency and co-agency are important.

This paper expands on the methodologies commonly employed in the field by stressing the benefits of using *agency* in settings where change is a central aspect of transitions in general.

5.1 Limitations and future research

A limitation of this study is its lack of generalizability, since it only consists of a single, in-depth case. Nevertheless, there is no indication that the applicability of the developed method is limited to larger groups of students (30-60) in their graduation year of the Department of Engineering at Technical Faculty of Amsterdam University of Applied Sciences (The Netherlands). This individual design proposition has already been used in smaller groups (4-12 students), in other years of the study programme (2nd year of study Engineering), and other programmes within Engineering (Sustainable Energy Systems). The evaluations among these students and lecturers show year after year that the results are without exception very positive.

This study provides numerous opportunities for future research. Firstly, this study identifies an opportunity for studying other factors and their effect on the development and motivation of students. For example, a more inclusive socio-technical approach through collaboration between students and lecturers of Engineering and other faculties/departments such as Society and Law, Fashion Institute, International Business, or Built Environment. Therefore, the authors propose applying the developed methodology with a strong focus on student agency using 'Innovation Consultancy Firm Method' in another educational programmes with significantly different academic areas, in order to determine it usability. Secondly, this study has now been conducted among students affiliated with one University of Applied Sciences in The Netherlands. It is in the context of the pursuit of sustainability, accelerating the sustainability transition, co-habitation, and co-existences to investigate an international collaboration. It is recommended to set up a virtual Innovation Consultancy Firm in collaboration with one or more Universities of Applied Sciences in other countries in Europe or even worldwide.

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TEACHING 'HOW TO SKETCH VISUAL STORIES' TO A PROFESSIONAL AUDIENCE: A TAXONOMY OF VISUALISATION STRATEGIES

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ABSTRACT
Scholars in design agree that sketching is of great value to the process of design and development. Whereas its origin lies in the sketching and presenting of tangible (industrially designed) products, the discipline has, since the 2000s, extended in various ways, along various dimensions. Various authors have addressed and discussed the most prominent change within the discipline since: the addition of so-called 'storytelling visuals': sketches of processes, overviews, systems and e.g. journeys [1, 2], also named 'visual thinking'. In fact, sketching as a means of communication has grown across discipline borders, and, as a consequence, the activity of sketching for communication enjoys a growing group of actors and audience these days. One particular course, a so-called 'Master Class', which is an intensive two-day taking course, taught to an external audience, focused on 'how to sketch visual stories', was subject to an experiment. The course was designed according to specific requirements (audience, pedagogy) [2]. Secondly, in order to assess the logic of the structure and the quality of the short course's structure and contents, participants were asked to fill out a questionnaire. Together, this experimental set-up, the questionnaire results, and the sketched output of the Master Class have led to new insights, to new knowledge that will help improve the pedagogic approach of many of the current courses taught and to the follow up Master Class in particular.

Keywords: Visualisation, sketching, visual-thinking, process-sketching, design, drawing

1 INTRODUCTION: ADDING STRUCTURE TO THE EXPANDING DISCIPLINE OF DESIGN SKETCHING

Whereas the origin of design sketching lies in the visualisation of tangible (industrially designed) products, the discipline has, since the 2000s [1], expanded along various dimensions. The expansion is a consequence of (1) new trends in the field of industrial and product design: i.e. the addition of early (strategic) stages to the design consultancy portfolio [3], and (2) the general trend present in various fields: the increasing use of sketches to display processes, overviews, systems and e.g. journeys, to enhance communication [1, 2]. As referred to by Hoftijzer and Sypesteyn [2], the expansion is aligned to a larger trend that concerns the visual medium in general: imagery is becoming central to communication and meaning-making [4]. These developments have – to summarize - led to the addition of 'visual storytelling' to the discipline of design sketching. In this paper, visual storytelling considers the use of sketching tactics, methods and skills, to draw story elements and linking elements resulting in one single visual representation (a 'praatplaat', in Dutch). See Figure 1. Mostly, such a visual representation comprises advanced perspective grids, a variety of story elements (among which, people), together 'telling' a story that either has a sequential nature or not. Some examples of companies offering the expertise of 'visual story telling' are Ink, Illustrategie, JAM, Flatland, etc.

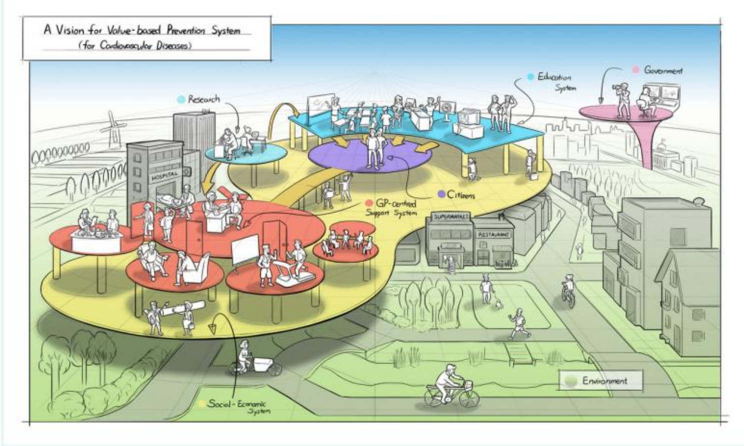


Figure 1. Example of a visual story telling (a 'praatplaat', in Dutch)

Along with the extension of the design sketching field, the activity of sketching enjoys a growing group of actors and audiences these days. Sketching increasingly receives the attention from disciplines as social sciences, engineering sciences, from strategic and tech consultancies.

2 A PEDAGOGIC STRUCTURE AND TAXONOMY OF VISUAL STORYTELLING

2.1 The need for structure: pedagogy and taxonomy

Both developments mentioned in the introduction, have resulted in changes concerning design education and design sketching education in particular. Given this expansion of the discipline of design sketching, as discussed in the introduction, there is a need for a new pedagogic structure. Based on the recent establishment and development of new sketching course content, aligned to these new areas, and the teaching of these courses, the authors developed a novel and generic pedagogic system to support this: (1) a pedagogic approach, and (2) a taxonomy of visual story telling strategies.

2.2 A pedagogic approach: starting with basic elements

Firstly, the structure of teaching (the pedagogic step-by-step agenda) of the Masterclass was aligned to the insights and knowledge as presented by Hoftijzer and Sypesteyn [2]. That pedagogic approach links the sketching of abstract content to the basics of design sketching (the latter being described by e.g. Eissen [5], Robertson [6] and Hoftijzer [7]). Secondly, the structure comprised a sequence of steps that would steadily help the participants to run the process stages from drawing story elements to sketching their own story. Elements that were specifically addressed were e.g. 'rich' sketches (clear, informative, and accurate [2]), relationships, tactics, simplicity, sketching pace.

The *first day's programme* concerned: Speed sketching / Visual note taking (effective and rich) / introduction lecture / 'Pictionary' / sketching tactics / 'how to make toast' [8]. The *second day programme*: 'treasure hunt' / lecture concerning sketching tangent things v abstract things / sketching system overview / introduction of taxonomy / implementing in participants' cases. These steps aimed to train the participants starting from fundamental (pedagogic) elements to sketching their own professional story/journey. The sequence of exercises and little breaks was 'larded' with instruction presentations, but most of the time people were sketching.

Manageable success creates a sense of competence

The creative mind boosts within a relaxed and confident setting. When the aim is too high or the demands seem too difficult, stress and fear of failure reduce the sense of competence, resulting in diminished confidence in a successful result [9]. This is also the case when the quantity of variables within an assignment are perceived as too many. Practically, this means that people's creative brain is to be unlocked by small, isolated exercises that connect elements of theory to practice. This serves as a reasoning for the implementation of small sequential steps within the structure of the Masterclass, from small elements to the final story.

2.3 A taxonomy of visual storytelling strategies: templates

The authors provided a fixed set of templates for the participants to use when designing their visual story set up (

Figure 2). The templates provided explicit starting points for the participants, to structure and compose their story. The templates can be seen as strategies for visualising. At the same time, the templates formed examples of what visual storytelling could look like. To offer a variety of possible ways to structure a visual story, the authors used different analogies for the design of the different templates. Based on a thorough exploration of existing story telling sketches, these analogies represent five different and distinct ways in which story elements can be related to each other, concerning e.g., hierarchy, dependency and sequency. However, mixing, combining or extending one or more of these five templates, in order to make them better fit the story that needs to be sketched, is definitely supported by the authors. The proposed taxonomy of storytelling sketches concerns:

a. The Iceberg. This category considers 'visualizing the 'seen' vs. the unseen', or 'what lies above/ beneath the surface?' This template structure suits stories that aim to convey the hidden reasons causing a specific outcome or phenomenon.
b. The Roadmap. This category considers the visualising of a sequential process. This template structure would suit stories or processes that aim to convey the stages, the changes and the context (factors) that define a specific process (of distribution, production or any other path that is run).
c. The Stepping-stones. This category supports the visualizing of certain milestones within a (mostly) sequential storyline. This story focusses on these 'gates'.
d. The Solar system. This category considers the visualisation of a core subject and all its relations positioned around it. This format would suit a visual mind map: the centre problem, with all sub-problems or solution directions structured around that problem.
e. The System overview. This category considers all the elements of a system. This could concern any combination of connected or related elements. Typically, this format concerns a composition of interdependent stakeholders or core elements, clearly linked to each other through the use of lines and arrows.

Pictures of the five 'strategy templates':

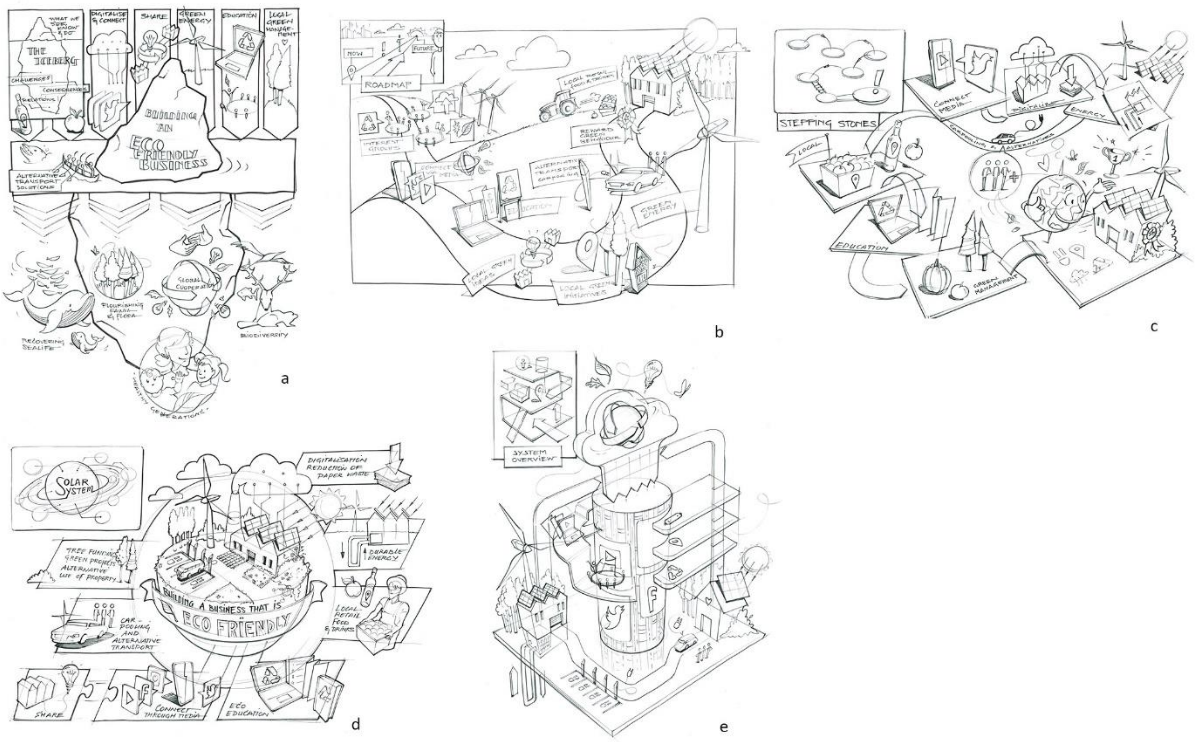


Figure 2. The five templates for story telling sketches

To serve as an example of what the end result could look like, all provided templates considered approximately the same subject.

3 EXPERIMENTS: A MASTERCLASS FOR AN AUDIENCE FROM INDUSTRY

3.1 Method: a questionnaire

In order to test the authors' hypotheses being (1) the pedagogic approach (see §2.2) and (2) the templates representing the taxonomy of strategies (see §2.3), a test was conducted by offering a Masterclass called 'visualization' to professionals from various industries. Part of these professionals were designers, and part of the group was not, which answered to the desire to test a group with various levels of sketching experience (as the goal was to serve a non-homogeneous audience).

Authors performed a test both (1) concerning the pedagogic approach and (2) the implementation of 5 different visual storytelling templates/ examples (the taxonomy). With a questionnaire and by observing the behaviour and results of participants, the authors were able to deduce the value and accuracy of what was provided in the Masterclass. The experiment (and questionnaire) concerned the three areas of alignment, structure and learning, see §3.3.

3.2 Masterclass set up

The Masterclass was offered within the context of the range of Masterclasses called IDE-MC, organized by a Dutch industrial design institute. The Masterclass concerned two days of sketching exercises and implementation, facilitated by three experts (the authors). Most of the exercises were executed on paper using fine liners, pens, markers. Some were done digitally, using an iPad or Wacom.

The participants were 13 professionals of which 5/13 designers in practice. Most of the participants had reasonable experience in sketching. They represented companies as Maersk, Zilveren Kruis, Windesheim, Coors, Koen, Boon Edam, Pan Oston and Laudea. The participants were asked to bring a specific case that referred to a potential professional situation for them, in which they were to apply the gained insights and knowledge.

Figure 3. Photos during the Masterclass

3.3 Hypotheses

Alignment

1. The Masterclass matches the prior knowledge of participants.
2. The knowledge and skills are directly relevant to the participants' professional daily practice.
3. The Masterclass enables participants to explore the subject further, on their own.

Structure

4. The lecturers structured the Masterclass well.
5. The Masterclass timetable and duration were appropriate.
6. The provided Masterclass materials supported the content.

Learning

7. The Masterclass contributed to the participants' learning experience.
8. The Masterclass improved the participants' expertise in this subject.
9. The Masterclass will help participants to apply specific knowledge, concepts and theories.

Additional to these survey hypotheses, the authors asked about the overall relevance, the overall organisation, and the overall score participates gave to the Masterclass. These are represented by questions 10, 11 respectively 12.

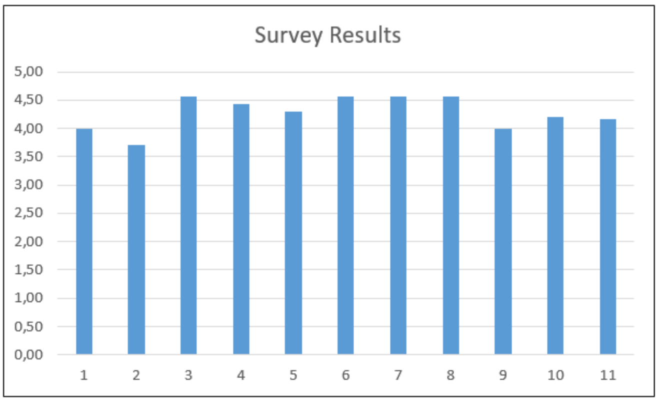
10. How would you rate the relevance of the Masterclass?
11. How would you rate the quality of the organisation of the Masterclass?
12. What would be your overall score for the Masterclass (scale 1-10)?

4 RESULTS

4.1 Numerical answers to the questionnaire

Table 1. Numerical results of the questionnaire

Question		n	scale	average (max 5)	deviation
1		7	1-5	4,00	0,82
2		7	1-5	3,71	0,49
3		7	1-5	4,57	0,53
4		7	1-5	4,43	0,53
5		7	1-5	4,29	0,76
6		7	1-5	4,57	0,53
7		7	1-5	4,57	0,53
8		7	1-5	4,57	0,53
9		7	1-5	4,00	0,58
10	Relevance	7	1-5	4,21	0,53
11	Organisation	7	1-5	4,17	0,76
12	Overall (scale 1-10)	7	1-10	8,71	0,76



4.2 Answers to the open questions

Most valuable

- What aspects of the Master Class were most valuable to your learning? Why?

Answers: the *basic sketching techniques* / visualisation concept development / visualisation tactics / hands-on drawing / interaction & feedback / That visualisation concerns both the result and the process / Fast sketching and scenario sketching / Visualisation of stories / strategies / being pushed to sketch, that is not common for me, was great / the teachers are excellent / dare to draw again + story telling.

Options for improvement:

- How can the IDE Master Class programme further enhance your professional level and personal development?

Answers: Build on the above / emphasize form giving and design sketching / add half a day digital drawing exercise / have no clear idea on this yet / the basics were just repeating for me. This part could have been shorter for me. Or perhaps more options in exercises, depending on your skills and prior knowledge / *some basics (like drawing thin lines, straight lines, circles) could have been a preliminary DIY video lesson /* the non-manual (computer) drawing techniques could be best added as an extra lesson online / A bit too much games / no time to include exercise for digital drawing / Maybe to get a bit more freedom of choice about the subjects/topics the description of the content and what actually happens in the room can be unexpected for people who is not close to the Design world / I attended with no idea that we would be drawing so much. I loved it but I wonder if that is clear when you see the announcement.

On top of the numerical answers from the questionnaire, participants were very helpful in providing feedback, both positive and referring to options for improvement. The authors will search for ways how to implement many of these suggestions.

4.3 Observations

In implementing the story telling templates on the second day, some participants combined one or two categories in order to suit their own project. For the authors, that was very interesting to observe and guide. It was clear that participants felt comfortable to improvise. Overall, all participants were clearly thinking while sketching, and thinking through sketching: how to visualise, what is important, how to convey my message best? The templates provided structure, guided the thinking process. The templates served in various ways for participants on different levels of visual skill and storytelling, either as a framework for the placement of their story elements and to define internal and external relations, or as a reference to create a template for themselves. The templates increased the practicability for the coaches and the effectiveness in demonstrating techniques within the Masterclass structure. The templates served as a tangible take away for the participants. Being able to experience the differences explicitly by comparing the different outcomes of different templates, gave participants a deeper understanding of visual storytelling.

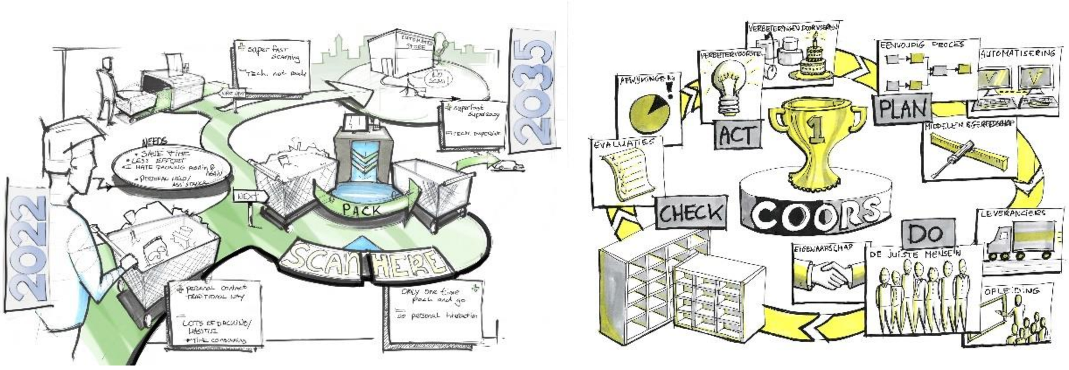


Figure 4. Examples of participants' outcome

5 DISCUSSION AND CONCLUSIONS

The Masterclass experiment led to great results, high evaluation grades, and participants provided very helpful suggestions. This tells the authors that both the pedagogic structure and the taxonomy of strategies (the templates) were accurate, and suitable for applying in education. There was some discrepancy between some of the open question answers: some suggested addressing basic knowledge more, whereas someone else suggested providing this content in a separate video. The authors will consider this; such an approach might help to cater the level differences within the group: differences in prior knowledge. Generally, although most members of the audience were educated in design, the authors served a non-homogeneous and professional audience. Because of the non-homogeneity, the tested approach seems suitable and applicable to a variety of courses and programmes, as the population at the university tends to be quite non-homogenous as well. Not all participants responded, which is why this study should be considered a qualitative review, not as quantitative research.

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A DISCUSSION TO LEARN ABOUT SUSTAINABLE WELFARE SYSTEMS FUNCTIONING

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ABSTRACT
A typical approach when designing a system for social service functioning in the European and Norwegian contexts is to emphasize what does not function—i.e., one does not ask for reasons behind the existence of conforming or agreeable behavior; rather, it is divergent behavior that is studied. A consequence of such a perspective may produce research designs and develop projects seeking to understand and describe phenomena such as alienation, vulnerability, and feelings of malfunctioning. To elaborate, such studies aim to describe relations rather than differences; the latter can be understood as the former. However, difference, as per Niklas Luhmann's understanding, indicates how relational descriptions are always logical and causal and thus lack the descriptions of paradoxes that produce agreeable functioning. Design based on causality may lead to the implementation of specific plans, while design that builds on the understanding of societal functioning as something that can emerge out of what seems paradoxical may lead to the design of a direction for a system. In this article, we will discuss how design processes that seek to implement a plan may differ from the processes that aim to initiate a direction in the context of public services. We will describe these differences through existing descriptions and exemplify their differences in functioning through the notions of maintenance and the value of care. A sustainable welfare system has the following characteristics: 1. With one or more meaningful, moral, and satisfying goals, the system offers a sense of sufficiency. 2. Positive feedback loops are balanced by negative feedback loops at an appropriate scale. 3. The system possesses clean, clear, fast, and compelling information flows. We protect our resource base so that it is resilient and capable of self-organizing and evolving. These dimensions will be discussed further in relation to how the functioning they create influences democracy through the behavior they produce.

Keywords: Method development, systemic design, cybernetic, systems thinking, sustainable welfare system

1 PLAN, DIRECTION, AND DEMOCRATIC VALUES IN DESIGN

Design pedagogy in problem solving has roots in rational and causal thinking. This thinking is widely used in service design. In this paper, we discuss how alternative approaches may foster holistic and therefore robust design solutions but with less certainty.
Niklas Luhmann et. al. emphasizes, in the book *Sociological Theory* [2], the usefulness of moving from *rationality enlightenment* to *complexity clarification* to understand societies. This involves recognizing social systems as complex. With such recognition, a rational way of thinking to understand societal functioning will be less logical and applicable. According to Luhmann et. al. , "systems lack reason" [2]. By this, he means to urge us to accept the uncertainty of society—i.e., its contingent character [2]. The main problem with reason, according to Luhmann, is that "rationality can only be one rationality" [2]. This means that in exceedingly complex systems, rationality is a tool that is insufficient, since logic only refers to singular situations. Therefore, one must work with methods that handle complexity.
How can one understand rational ways of thinking while designing for societal functioning? The single orientation of rationality typically leads to a plan, and such a rationally justified plan can be exemplified by trying to tackle what are considered problematic behaviours or experiences. They are often described as pain points in a service design process and are identified through blueprints [4] that result in change proposals through service journey descriptions. The problem with such a focus is as follows: First, in complex contexts, paradoxes often emerge—meaning that a service can work despite stimulating

unwanted behavior [2]. This means that a change in a system may create more problems than the removed problem. Second, a blueprint is a current description consisting of empirical data without abstractions [5], which does not take into account the functioning of systems in the face of change. Third, service journey descriptions relate to the present picture and not to complex dynamics that can describe influences independent of time, defining future service design and thus functioning.
One of Luhmann's points here is that there is as much to learn by studying functioning as there is by examining dysfunction. Luhmann suggests that one can replace rationality with observation of the complexity of social systems and observation of the observation [2]. By such observation, one can describe systems functioning (such as a public welfare system), the environment, and the relation between the two; this relation is what Luhmann calls difference.

1.1 Mead on plan versus direction and values

Rational thinking as a basis for design then leads to focusing on problems and planning. Margaret Mead [4] states in her article "The comparative study of culture and the purposive cultivation of democratic values" (1942) how "blueprints" and planning for defined ends lead to the manipulation of individuals, which in turn leads to undemocratic system functioning [4]. She further highlights that by working in terms of values that are limited to defining a direction, it is possible for us to use scientific methods to control the process without the negation of the moral autonomy of the human spirit [4]. When leading in a value-based direction, treating people in the system as things can be avoided—e.g., in a linear paradigm, such as in the instrumentality of hard science, and when building a ship, the process has an end result namely a ship and the process involves handling tools and other objects. In the social sciences, the tools are people, and people learn [4], in contrast to things that can be handled and controlled.
In other words, you can ask where the plan comes from. Often, the plan emerges from causal thinking through diagnosing the social system with unwanted symptoms. The typical descriptions of such symptoms are school refusal, school dropouts, feelings of alienation, drug addiction, and so on. Moreover, focusing on problems thus represents plan-based thinking and not directional thinking. Planning is useful when dealing with static systems that can be understood as linear, not when working with complex, living systems dealing with wicked problems "with no definitive problem formulation and no 'stopping rule.' In other words, these problems lack an inherent logic that signals when they are solved. Their solutions are not true or false—only good or bad. There is no way to test the solution to a wicked problem" [6].
Mead describes the state of mind created by shifting toward the habit of "learning to learn," as seen among the Balinese: "The treatment of children is such that they learn not to see life as composed of conative sequences ending in satisfaction, but rather to see it as composed of rote sequences inherently satisfying in themselves" [4]. She recommends looking for value in the act itself rather than regarding the act as a means to an end [4]. Donella Meadows states that "mindsets" (leverage point 2) [8] are above the function or purpose of a system because they inform the functions and goals created by the people in a system. Value-based leverage (leverage points 1–3) as well as human-related leverage (leverage points 1–6) are formulated by Meadows as places with the highest capability to influence change in dynamic, complex systems, or living systems [8].
An interesting differentiation is that a direction involves an inherent value in the act itself [4], which can be seen as an essential part of the maintenance process of caring for a living system designed based on values, rather than as a means to an end [4].

2 CAUSAL THINKING

When recognizing the phenomenon of causal thinking, one will follow a temporary development that conveys the persuasive argument that consequences would not have happened if the cause had not existed [2]. This thinking often leads to a design that contains a plan, as described by Mead [4], with a one-way progression from a point of departure, defined as unwanted behavior to a favoured situation. Thus, by recognizing a cause as a basis for understanding a context, and changing by design, one neglects seeing systems with information about a wide range of dynamics, possibly defined by delays, reinforcing, and balancing loops, among others, and by the creation of multiple other subsystems, all of which may react when intervened. Removing a problem, according to Luhmann et. al. may then lead to the unintended emergence of what Forrester called counter-intuitive systems and a general lack of understanding of the context studied [7]. Moreover, designing based on not having defined ends but intended functioning may be understood as direction thinking. Due to the widened scope of time and functioning, such an approach will produce a continuously fluctuating dynamic image, defined by various feedback loops between units, delays, possible buffers, communication flows, and coding, among others [1], which is more complex. The uncertainty that such an understanding creates the complex image it communicates may be why people choose to utilize causal thinking that is easy to understand. However, understanding data in a broader context and at different levels of abstraction can help designers make more informed decisions.

3 SYSTEMS CODING

Social systems are exceedingly complex and self-productive; however, they are less complex than the environment outside the system [1]. Such systems can be analysed by describing the levels of operations and analysing input–output, feedback loops, and relations, among others. An additional way of understanding social systems functioning is to describe the language or coding that the system uses to operate. Such coding can be understood as information that leads to binary switching. For example, in finance, the coding can be understood as payment–not payment; in science, true–not true; in law, legal–not legal; and so on [1]. In fact, such codes are described by Luhmann as universal and general [1] in a way that everything that is within the domain of relevance for the system belongs to one or the other value: "The more complex the coding is, the richer is the variety of (internal) processes that the system can operate" [1]. This can be understood as the capacity to communicate with the environment (outside of the system).

4 SOCIAL SUSTAINABILITY WITH REFERENCE TO PLAN AND DIRECTION

Meadows posits that "to be socially sustainable, capital stocks and resource flows must be equitably distributed and sufficient to provide a good life for everyone. If we wish to create a sustainable world, we must take into consideration and fulfil these biophysical necessities of sustainability" [8]. She built on the three biophysical necessities of sustainability, as coined by Herman Daly, stating that when using common resources and releasing pollution, balanced use and release are necessary [10]. Every renewable resource must be used at or below the rate at which it can be regenerated or regenerate itself, whereas every non-renewable resource, such as our fossil fuels, fossil waters, and minerals, must be used at or below the rate at which a renewable substitute can be developed. Furthermore, every pollution stream must be emitted at or below the rate at which it can be absorbed or made harmless by the natural systems of the world [10]. The tragedy of the commons, according to Garrett Hardin, is defined by an unsustainable system function where the mentioned needs related to the sustainable use of shared common resources in society are not met [9]. On the contrary, the tragedy of the commons can be described as a reinforcing feedback loop where exploitation is the driving system behavior that will lead to eradicating the resource.

As described in systems theory, Meadows' systems (for example) may be understood as having a goal or direction—i.e., one cannot foresee a system's exact functions or specifically say what a system seeks to reach. In any system, new behaviours and functions emerge because of other functioning's. Such subsystems may function in line with the intention of the main system that has created them; however, they may work counter to the intention of the initial system [7]. Further, growth as a goal involves asking for unsustainability on a finite planet [8], while goals must be related to real human fulfilment, not just acquiring more. A sustainable system can be socially equitable and culturally committed to our common resource base, as it is our life-support system [8].

Therefore, how does a sustainable system look? It has the following characteristics:

1. With one or more meaningful, moral, and satisfying goals, the system offers a sense of sufficiency.
2. Positive feedback loops are balanced by negative feedback loops at an appropriate scale.
3. The system possesses clean, clear, fast, and compelling information flows.
4. We protect our resource base so that it is resilient and capable of self-organizing and evolving [8].

An interesting differentiation when describing a direction is that it is a value-based vision of a different system state. In addition, a plan contains concrete actions intended to achieve a goal. It can be considered short-term in contrast to visions, which can last centuries. Envisioning a sustainable future, the theoretical discussion in this paper suggests describing a direction, not a plan.

5 WELFARE SYSTEMS AS DESIGN CONTEXTS

In this paper, we discuss welfare system functions based on our ontological experience with the Norwegian Labour and Welfare Administration (NAV) on two levels: level 1 is the communication system existing between the users and NAV, while level 2 is the overall service development necessary for the system to function. At level 1, NAV does not have an overview over all communications with its users in the different public channels offered by NAV. The communication is typically initiated out of new needs that emerge among users due to the occurrence of events in their daily lives or to limitations in the communication systems that are not met by the current system. Such events may include new rules or regulations, new practices, infrastructure failures, and so on that cause users to contact NAV. Further, the emergent need creates new subsystems. For example, new businesses emerge providing services guiding users in how to reach NAV, lawyers offering their services to act on user's behalf in communication with NAV, external emergent websites, Facebook profiles and so on creating businesses on the basis that NAV services are difficult to understand and that it is difficult to get in contact with NAV.

To understand the communication systems at NAV, it may be helpful to describe systems functioning through communication, apart from describing how to produce information with individuals benefiting from the welfare system. In general, one could say that the design section of NAV strives to create a communication system designed to meet the needs of users and is easily accessible. Further, it ought to be reliable and consistent and provide clear and concise information. It is essential also to be responsive and able to adapt to changing needs and circumstances, prioritize user privacy and security, and secure stable communication to create a trustworthy relationship between NAV and its users. Typically, the coding of individual user communication is based on; *support–no support*, *payment–no payment*, and *correct documentation– incorrect documentation*, among others.

In addition, the second level of overall service development involves processes of continuous improvement to both the digital services and follow-up services delivered from local, physical offices, where users can meet with their supervisors. This level involves understanding the context of welfare systems functioning in relation to all actors in the public and private sectors under government instructions. The service thus relies on understanding different codes, as described by Luhmann et. al. [1], as instructions from the government come from the finance department with *payment–no payment* coding and the judicial department with *legal–not legal* coding.

This coding or language can be identified as or is in alignment with the direction of a system. For a welfare system, a direction may be based on values such as *individual autonomy*, *care*, *democracy*, *sustainability*, *empowerment*, and *emergence flexibility*, while the other end of these functions may be based on, *manipulation, neglect, totalitarianism, unendurable control, a static state/ rigidity*, and other similar aspects.

6 DESIGNING SOCIAL SUSTAINABILITY

As Meadows emphasizes, social sustainability involves the fair distribution of care, democratic governing, and fair treatment when care is needed. The question, then, is how to design for a fair distribution of care and democratic governing? Due to the complexity of the societal circumstances in which designers seek handle through design interventions, we find that the combination of the theory introduced in this article produces an interesting starting point for thinking and learning about sustainable welfare systems functioning.

6.1 Understanding the design of sustainable welfare systems in relation to the presented theory

On the one hand the synthesis of the theories by Mead and Luhmann et. al. may lead to the understanding that rational thinking is related to causal thinking and that causal thinking is related to the development of plans, not directions. In many ways, a plan can be easily created without looking into any system dynamics, potential, or other types of functioning; yet it can seem strategic because it is concrete. A plan can thus be presented without information about how it will influence the system in which it is meant to function. Causal thinking, as the origin of a plan for a design process, can then be understood as linear, and one is locked in the process of continuously having to solve the next step or situation considered problematic based solely on information produced in the context of what the design and plan produce.

6.2 Designing a direction

A direction needs to be understood as an ongoing process and must therefore contain information about how it or any suggested intervention within a direction influences society or a system. We can investigate the suggestion by Mead [4] to design for a direction and not a plan and try to understand how this can be completed through the theory presented in this article. First, in the initial phases of the design process, one can try to neglect the concept of causal thinking and instead seek to describe the dynamics of a system by observation and the observation of observation to be able to visualize the complexity, functioning, and further, meaning of the system, which may help to set a direction for the system and design intervention. By orienting the design work in such a way, one would have to leave the persuasive argument of knowing what will happen through the design intervention and rather describe how the design is able to resist and adapt to the changing environments to which it will be exposed. Of course, one would need to abandon the traditional design philosophy that promises certainty based on cause-and-effect rationality.

To elaborate, when considering a direction, it is not the direction itself that is of importance for analysis but what it produces. Contrary to a plan that highlights a final result within a certain period, a direction offers an objective as functioning regardless of change, such as the distribution of care, democratic governance, and fair treatment. The mindful act of maintaining systems functions follows such a direction in the present rather than in the future. Descriptions of direction benefit or demand the mapping out the complexity in which the system is to function. With such an analysis and the resulting descriptions of complexity and manifold feedback loops, the line of the system with a direction may be more adaptable and may support the intended direction, even though it is disturbed by the outside environment.

According to Mead [4], plan thinking leads to manipulative and discriminatory processes and is undemocratic. The NAV system itself creates problems due to the laws that must be enforced or administered through its processes, turning functioning people into labelled, classified individuals. There is a circularity in the system where the plan creates what it is supposed to prevent. For NAV to work in a different direction, a different type of order should be initiated with noise and disruption to the system.

6.3 Understanding the direction for design in light of coding

The concept of systems coding or a binary language may contribute to an understanding or a way of approaching design for sustainable welfare systems. Designing for a direction in a welfare system without understanding systems coding may lead to designs that the entities (people) or the communication system itself cannot operate or understand. For example, one cannot introduce the concept of system direction to a social system that only understands plans. This is because plans involve cause-and-effect thinking and thus the design of ends, and when there is no plan or end presented, there is no possible logic to which to respond. To be able to communicate with the social system thus, one needs to know the coding that can be subsequently compared to other types of coding that use additional qualities as system outputs. If a social system is concerned with cause and effect, or the problem–problem solved type of thinking, the presentation of the quality equal distribution of care does not fit the logic. Accordingly, it is not the disliking of the thinking that makes the social system avoid such an idea; rather, it is the system's ability to use the information. However, presenting the understanding of pain points detected in a blueprint description, in fact, comes from a cause-and-effect type of thinking and may lead to the awareness of the existence of alternative codes.

6.4 Adopting Social sustainability and design in social welfare systems and mindful observations

According to Mead and Meadows, understanding the act of maintenance itself is valuable, and the power of mindsets can inspire direction. Discovering specific descriptions of values in the act of taking care of a living system, such as a welfare system, is a way of understanding how to start working with a direction and not a plan. It contains a shift in the mindset to being in the moment, mindfully observing and taking care of the welfare system's vital functioning, such as communication, instead of working toward a goal in the future. Therefore, how may a systems perspective provide new insights for students and practitioners working with exceedingly complex situations and developing ways of co-habiting spaces and sharing resources with each other?—regardless of whether it involves other cultures, other species, or the diverse eco-systems that support us? A functioning system may be facing intervention at a systemic level—e.g., changes in the structure of the design itself through UX solutions and the application of metaphors or intuitive design elements that do not touch into or change the system's functioning. Finally, a system may be seen as something that will continue anyway; maybe one should alter the perspective of what change can be made within a system to create an inclusive, fair, and pluralistic future.

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SHAPING SMART HOME PRODUCT SERVICE SYSTEM (SH-PSS) REFLECTION CRITERIA CARDS FOR 'TILES IOT INVENTOR TOOLKIT'

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ABSTRACT
The rapid growth of the Internet of Things (IoT) has provided new opportunities for the development of Smart Home Product-Service Systems (SH-PSS) as technological solutions to various problems. However, designers face challenges in generating ideas for such systems. This study aims to address this challenge by developing an extended Tiles IoT Inventor toolkit specifically designed for SH-PSS design. The toolkit utilizes a card-based approach to identify consumer problems and explore the technical capabilities of SH-PSS during the ideation process. To assess its effectiveness, the IoT Ideation toolkit was evaluated through workshops involving user experience designers, product designers, and human-computer interaction (HCI) students. Additionally, this study identifies five attractive characteristics of SH-PSS that influence technology adoption and introduces SH-PSS Reflection Criteria Cards as part of the Tiles IoT Inventor Toolkit. Research questions are formulated to investigate the enhancement of idea generation ability, service dominance and the identification of technology adoption discontinuities using these reflection criteria cards. Hypotheses are proposed and will be tested through experiments involving control and experimental groups. This study contributes significantly to design education, providing valuable support for design practitioners and researchers in identifying consumer problems and exploring the technical capabilities of SH-PSS.

Keywords: Smart home product service system, experiment design, card game design, ideation toolkit, Tiles IoT Inventor Toolkit

1 INTRODUCTION
The design of smart home product-service-systems (SH-PSS) entails the creation of smart home products and services that fulfil consumer needs and expectations, offering a seamless and integrated experience across various connected platforms and products. Designing SH-PSS involves understanding user requirements, comprehending the smart home ecosystem, and crafting engaging user experiences. However, the design process faces challenges such as interoperability, security, complexity, compatibility, user experience, and privacy, which must be addressed to ensure successful adoption and utilization of SH-PSS. One research gap in this area is the lack of a framework and toolkit for PSS-designers to facilitate the design of technology-based interventions within the context of smart homes. Thus, this study aims to develop an extended Tiles IoT Inventor toolkit tailored specifically for SH-PSS design. The customization of the generic Tiles IoT Inventor toolkit focuses on key considerations such as context awareness, multifunctionality, cooperative capabilities, personalization, and openness in the smart home context. The developed toolkit will be evaluated by formulating hypotheses (Table 3) to address the research questions (Table 2).

2 LITERATURE REVIEW

2.1 Characteristics of Smart Home Product-Service-System (SH-PSS)
While perusing the literature, we learned that the adoption of SH-PSS by a consumer is influenced by the qualities of SH-PSS consumers looking for and product smartness[2,11,15,16]. Product smartness refers to the qualities of products which are intelligent and smart. **Product Smartness:** The literature discusses qualities that define a product as smart [2,16]: independent, adaptive, reactive, multi-

functional, ability to cooperate, humanlike interaction, and personality. **Quality consumer looking for in SH-PSS:** In previous studies various qualities, that a consumer looks for in a smart home product. These qualities are categorized as 'within the product', 'related to the usage of the product' and 'related to other products' [2,11]. These qualities are crucial as they will affect consumer behavior, on the decision to adopt smart home products. (a) Within product: Context awareness, Interpretation, Proactive, Self-description; (b) Usage: Personalisation, User friendly interaction; (c) With other products: Communication, Cooperation, Openness, Collaboration. In our previous study, we analysed all the above characteristics of SH-PSS through the Kano model approach. The kano questionnaire was designed using functional and dysfunctional questions for each characteristic. The relevant survey was performed with consumers (n=226) in the Indian context. The responses of respondents were evaluated using the kano evaluation table. Through this approach, we found five 'attractive' characteristics: ***context awareness, multifunctional, ability to co-operate, personalisation and openness***. Consumer satisfaction will improve dramatically with rising characteristics performance, but it will not drop with decreasing performance.

2.2 Design Process of SH-PSS

We have identified various design toolkits in the literature that assist the SH-PSS design process [3,6,12,13] based om the concept of Design by Analogy [1,8,18]. It helps designers in the ideation process by exploring the problems faced by the consumers, taking inspiration from existing intelligent systems, exploring the technical capabilities of the smart products and smart services, idea generation process, planning implementation and mitigating implementation problems. Identified toolkits in the literature are (i) Card'n'dice, (ii) Co-create the IoT, (iii) Design Desk, (iv) IoT Ideation Design Kit, (v) Know Cards, (vi) Mapping the IoT and (vii) Tiles IoT Inventor Toolkit [6].

In this study we have identified that designers adopt a process as six stage activity as design process of SH-PSS: exploring problems faced by the consumers, taking inspiration from existing smart systems, exploring the technical capabilities of the smart products and smart services, idea generation process, planning implementation and mitigating implementation problems (Figure 1). Since understanding the consumer's problems is critical while designing a personalized smart product as it increases the system's efficiency, which further helps them adopt the SH-PSS. In our study, we have specifically taken the Tiles IoT inventor toolkit, as it helps designers explore the problems of the consumers and the technical capabilities of smart products and smart services.

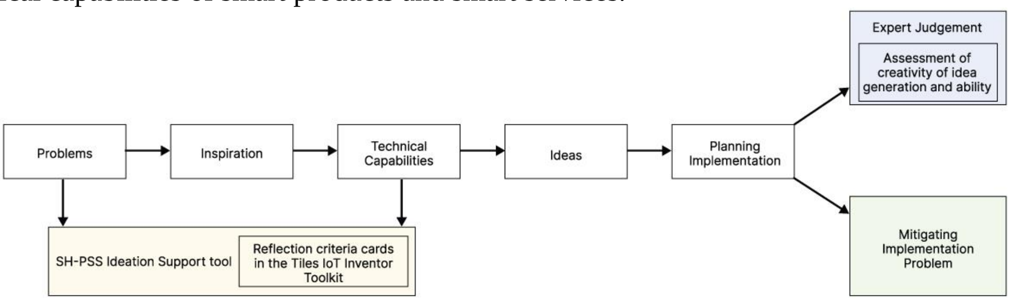

Figure 1. Ideation Design process of SH-PSS

3 RESEARCH METGODOLOGY

3.1 Design by Analogy

A classic definition of *analogy* is "the illustration of an idea with another idea that is similar or analogous to it in some significant features [8]. Design by analogy is a problem-solving technique involving using a familiar solution from one context as a model or inspiration for solving a problem in another context and developing innovative design, particularly during the ideation phase [1,18]. Designers use this method to produce creative designs. In product design, George Mestral's invention of Velcro and automobile design of the VW Beetle automobile form are some of the most cited examples of Design by analogy. Similarly, in product service system design, Design by analogy can be a valuable method to develop novel ideation. Meanwhile, Smith et al. (1993) demonstrated that analogous design might have a restricting influence on idea generation (fewer ideas are generated) and that unintentional transfer of negative design features may occur [5,17]. Therefore, it is essential to choose analogies wisely to avoid hindering effects in innovative design ideation and demonstrate the methods that keep the designer in charge of selecting analogies that may only be beneficial, as finding relevant analogies is often tricky. Taking inspiration from previous studies, we identified technology adoption characteristics of SH-PSS [2]. These characteristics were analysed using the kano model approach to identify the attractive features. These attractive features are analogies introduced as SH-PSS reflection criteria cards in the Tiles IoT Inventor Toolkit. This method helps select relevant analogies systematically over random selection.

3.2 Tiles IoT Inventor Toolkit

The Tiles IoT Inventor Toolkit is a modular, hands-on learning system designed to teach product designers, interaction and user experience designers about the Internet of Things (IoT) enabled smart products [6]. This toolkit is a fun and educational way to learn about ideation of IoT products and can be an excellent tool for identifying and learning the consumer's problems and exploring the technical capabilities of the design brief while ideating [6,13]. The toolkit consists variety of physical tiles or cards that can be connected together to create various ideas. These decks in the toolkit are scenario, persona, missions, things, human actions, sensors, services, feedback and reflection criteria [12]. These tiles are created to inspire ideas for IoT user experiences by fostering both divergent and convergent thinking. The playbook guides the participants in designing IoT enabled smart products in a seven-step process (Table 1). Although the ideation technique is meant to be supervised by professionals, the playbook helps keep the design process visible and minimizes the need for supervision.

Table 1. Activities participants are asked to perform in the Tiles IoT Inventor Toolkit

	Activities
1	*Start by selecting a **Persona** and a **Scenario** that you have agreed to focus on*: What specific needs or problems are you trying to solve for the user selected? You can place the chosen Scenario and Persona cards in the card placeholders at the bottom left corner of the board
2	*Refine the **Mission:*** Challenge yourself to think creatively about the purpose or mission of your idea. Use up to three Missions cards to challenge and guide your idea.
3	*What objects are central to your user?* What objects are central to your users and how they can help solving the needs you have identified? Look through the **Things** cards, select a few of them as your starting point and place them on the card placeholders in the THINGS section of the board.
4	*What actions trigger the Thing?* Explore what types of input are needed, whether they are **Human Actions, Sensors or Services** from a connected source. A **thing** can have multiple triggers, and the same trigger can affect multiple **things**. Place your selections on the card placeholders in the TRIGGERS section of the board.
5	*How does the object respond when it is triggered?* Responses allow the object to communicate back to the user when it is triggered, either by a direct **Feedback** from the object itself or by sending data to an app or service through **Services**. (RESPONSES section of the board)
6	*Flesh out the idea:* The Storyboard section of the board is your sandbox to describe and illustrate the idea you are working on. Try to make notes and sketches to show how, where and when the concept works and looks, and what it might feel like to use it. Imagine a story which depicts a use case for your object, you can sketch each step on a post-it and stick them in the boxes.
7	*Reflect and improve:* Look through different **Criteria** and discuss how well your concept scores on each. Select a few strengths and weaknesses of the concept and see if you can come up with improvements to resolve the weaknesses, you can change the other cards and the storyboard if you feel the need. Write down a brief description of the final idea in the Elevator Pitch box.

3.3 Experiment Design

For validating and testing the intervention in the toolkit through introduction of additional reflection criteria cards, we have formulated three research questions (Table 2), which addresses technology adoption, service dominance and idea generation's ability enhancement. To answer these research questions, we have planned the set of experiment, where two sessions were planned as it's part. In the first session, the participant ideated without the additional proposed reflection criteria cards (**Control Group-Treatment 1**), while in the second session the same participants ideated with proposed reflection criteria cards (**Experiment Group-Treatment 2**). In both the experiment session, the participants were asked to ideate for the given design brief. A total of 15 designers (user experience designers, product designers, and human-computer interaction HCI students) participated in the study through workshops.

Table 2. Defined Research Questions

	Research Questions
RQ1	Do these design ideations elicit technology adoption in significant number of the target consumer?
RQ2	What is the smart home PSS design framework with special emphasis to service dominance?
RQ3	How to customize the generic PSS design toolkit in the context of smart home PSS design considering context awareness, multi-functionality, ability to co-operate, personalization, openness? (Idea generations ability enhancement)

Figure 2. SH-PSS Reflection Criteria Cards for Tiles IoT Inventor Toolkit

4 RESULT

4.1 Proposed SH-PSS Reflection Criteria Cards for Tiles IoT Inventor Toolkit using Design by Analogy

Osborn (1953) suggested that the innovative solution emerges on breaking out of a conventional pattern, either perceptual or cognitive, which unlocks the way for a broader range of alternatives. The mind works on a pattern that leads to solving a problem under the influence of prior knowledge and may affect creativity [14]. Therefore, we have presented an intervention in the seventh step of the Tiles IoT Inventor toolkit process (Table 1), which is the introduction of five additional SH-PSS reflection criteria cards.

These reflection criteria cards are ***context awareness, ability to co-operate, multifunctional, personalisation and openness*** (Figure 2). The reason behind making it a card tool is that they are simple to understand and easy to manipulate. Physical cards make the design process visible and less abstract [7,10]. Moreover, they serve as a tool to communicate while designing in a team.

Hypothesis Testing: Control Group and Experimental Group: A group of participants will be recruited and randomly assigned to either the control or experimental group to ensure unbiased distribution of potential confounding factors. The control group will serve as a baseline comparison, receiving no specific intervention or access to the Tiles IoT Inventor toolkit. Both groups will receive a design brief for an SH-PSS project and engage in an ideation session. The control group will rely on their existing expertise, while the experimental group will utilize the Tiles IoT Inventor toolkit to assist in idea generation. Participants in both groups will document and submit their ideas for evaluation based on predetermined criteria such as innovation, feasibility, and relevance to SH-PSS design. The generated design ideas and evaluation scores will be collected for analysis, enabling a comparison between the control group's ideation outcomes without the toolkit and the experimental group's outcomes with the toolkit. Through this controlled experiment, the aim is to assess the impact of the Tiles IoT Inventor toolkit on idea generation in SH-PSS design, providing valuable insights into its effectiveness in enhancing the technology adoption, service dominance and idea generation’s ability enhancement quality of design ideas within the smart home context.

Table 3. Working Hypothesis

		Working Hypothesis
1	H_1	In the ideations, there is significant difference between ratings of peers on the **Perceived Ease-of-use** attribute, for a design concept in T1 and T2.
2	H_2	In the ideations, there is significant difference between ratings of peers on the **Perceived Usefulness** attribute, for a design concept in T1 and T2.
3	H_3	In the ideations, there is significant difference between ratings of peers on the **Context Awareness** attribute, for a design concept in T1 and T2.
4	H_4	In the ideations, there is significant difference between ratings of peers on the **Muti-functional** attribute, for a design concept in T1 and T2.
5	H_5	In the ideations, there is significant difference between ratings of peers on the **Ability to co-operate** attribute, for a design concept in T1 and T2.
6	H_6	In the ideations, there is significant difference between ratings of peers on the **Personalization** attribute, for a design concept in T1 and T2.
7	H_7	In the ideations, there is significant difference between ratings of peers on the **Openness** attribute, for a design concept in T1 and T2.
8	H_8	In the ideations, there is significant difference between ratings of peers on the **Service dominant** attribute, for a design concept in T1 and T2.

5 CONCLUSION

This study draws inspiration from a generic IoT toolkit and aims to make a focused toolkit for smart home product-service-system (SH-PSS). The SH-PSS reflection criteria cards (***context awareness, ability to co-operate, multifunctional, personalisation and openness***) in Tiles IoT Inventor Toolkit developed in the current study is through a structured approach for SH-PSS ideation. The proposed tool is devised based on the principle of Design-by-Analogy. The developed technique is a card-based tool representing the contextual meaning of each as a source of inspiration representing textual and visual cues for reflection criteria cards in the Tiles IoT Inventor Toolkit. In the last section, we have formulated a hypothesis to answer the research question, which addresses technology adoption (perceived ease of use and perceived usefulness), idea generation ability enhancement and service dominance. These hypotheses should be tested in the experiment with the control and experiment groups.

This study will be a significant contribution to design education, and it is expected that design practitioners and researchers will get help in identifying consumer problems and explore the technical capabilities of SH-PSS. It provides a structured framework and domain-specific cards that guide students in designing Smart Home Product-Service-Systems (SH-PSS), allowing them to grasp the complexities of SH-PSS design and consider factors like context awareness, multi-functionality, cooperation, personalization, and openness. The toolkit promotes a user-centred approach by incorporating cards related to scenarios, personas, missions, human actions, and feedback, encouraging students to empathize with end-users and develop a holistic design perspective. The toolkit also facilitates interdisciplinary collaboration, enabling effective communication and knowledge integration among students from different backgrounds, including user experience designers, product designers, and HCI students. By offering a common language and framework, it supports collaborative ideation and the development of comprehensive SH-PSS solutions. Overall, the Tiles IoT Inventor toolkit is a valuable resource in design education, empowering students with essential skills to tackle the challenges of designing user-friendly and innovative smart home products and services, preparing them for the evolving landscape of IoT and its applications in smart homes.

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MATERIAL DESIGN FROM INDUSTRIAL WASTE: AN EDUCATIONAL APPROACH

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ABSTRACT
Industrial design students are increasingly required to understand circular economy practices to produce more sustainable designs. One of these practices is waste minimization, which may involve reusing or remanufacturing residues. This article describes a project where waste materials from local industries were used to develop new materials, providing circular economy solutions. The project was conducted as part of third year Material Technologies and Sustainability courses in an Industrial Design Engineering programme, in collaboration with local industrial partners.

Over the course of four years, with four different waste inputs and a total of 180 students, the project resulted in the development of 12-20 suggestions for new materials for each industrial waste used. Of these results, 3 proposals for each material application were considered viable, environmentally beneficial, and interesting enough for further development. The project let students experience the difficulties of repurposing residues and showed that the developed materials aren't always more sustainable than their primary material counterparts. Students were able to learn about material properties in an interactive way, which could be useful for other Industrial Design Engineering academics looking to incorporate waste recovery into their educational practices.

Keywords: Industrial waste, material properties, industrial collaboration, circular economy

1 INTRODUCTION
Circular economy (CE) is a broadly established concept in sustainability, where waste and pollution are minimized, and resources are conserved by recirculating them into production to create closed-loop systems. Much research has gone into this field, with more than 114 reported definitions for CE [1]. Despite the proliferation in definitions, it has gained traction and has been incorporated into national and regional policies around the globe [2], [3]. The European action plan for CE even states that by incorporating circularity principles into the process of product design and manufacturing, designers can help create more environmentally friendly products that are efficient in terms of resource usage [3]. Therefore, it is seen as crucial to educate designers into CE principles, and one of the common strategies used in education and spontaneously by students, is to develop things from discarded materials [4], [5]. Education for the implementation of CE is seen as a subset of Education for Sustainable Development (ESD) [6]. Even if it addresses a specific aspect of ESD, the education for CE is rooted on the same principles and frameworks (e.g., systems thinking, complex socio-technical systems). A review of educational approaches for CE and ESD extracted three principles for the development of educational material applied: interactivity (learning by doing something rather than just listening), non-dogmatism (presenting both positive and critical views towards a subject), and reciprocity (continuously incorporating student feedback into the programme) [6]. To apply the interactivity principle, a common approach used is to challenge students to develop new materials and/or products using waste [7]–[9]. This real-world challenge is currently faced by industry when trying to prevent and/or minimize their waste generation and is therefore a useful skill. However real implementation of the ideas developed in the classroom tends to be difficult to accomplish [7].

This article reviews the implementation of a challenge to design new materials from industrial waste, applied in two third year Industrial Design Engineering (IDE) courses. It is presented as a new case study in this field, in the hopes of corroborating and/or challenging conclusions taken by similar educational experiences referenced above.

2 MATERIALS AND METHODS USED

This article reviews the materials designed from industrial waste over the last 4 years of doing this assignment. The final project reports and resulting prototypes were used to evaluate student proposals. The authors, all teachers involved in these courses, converted their academic evaluation of student work into the following three assessment criteria:

- **Technical viability:** Considers the potential for industrial scalability of the proposal, including few and simple production steps, little additional material, large quantities of the residual material, and potential application areas where the material implies an added value. This criterion has been influenced by the feedback obtained from the collaborating industries during the courses.
- **Material Circularity:** Considers how recyclable (technical cycle) or compostable (biological cycle) the proposed material is. Recyclability is considered slightly better since the material is kept in circulation, rather than "dissolved" as nutrients.
- **Environmental Impact:** Considers how much environmental benefit is obtained from using the developed material instead of an existing similar material on the market, for a given application.

Student results are evaluated with these criteria, using a 1-5 scale, with 1 being the worst evaluated and 5 the best. Combining the three evaluations, each project could obtain a maximum of 15 points.

2.1 Structure of the educational experience

The experience described in this study is linked to two courses that run in parallel for 3rd year IDE students. The first course, "Advanced Materials I", focuses on designing, developing, and characterizing materials by revaluing industrial waste. Students are encouraged to design "tailored" properties, using advanced materials that are increasingly present in the industrial reality, such as composite materials. Once they develop a material, the resulting properties are analysed and characterized at the laboratory and relevant fields of application are identified. The experience-based learning with new materials serves as a tool to facilitate the inspiration phase and help students conceptualize and develop new, innovative products with high value contribution. The specific competencies that the course seeks to impart, are from the material technologies branch, and include the use of creative processes in idea generation, applying knowledge of materials, technologies, and production processes to develop new products.

The second course, "Advanced Materials II", defines advanced materials as sustainable ones. The specific competencies the course imparts are about sustainable design, including the understanding of key sustainability concepts, relate sustainability to the use of materials and resources, quantitively assess a product's environmental impact, and to creatively propose design improvements to reduce the environmental impact. It builds on "Advanced Materials I", so students are required to identify an area of application for the developed material, propose a product, and develop a Life Cycle Analysis (LCA) for that product. Students are then expected to identify possibilities for improvement for both the product and the material, applying an iterative design approach. Students are required to compare the environmental profile of their proposal with existing solutions with an equivalent functionality, to validate the expected environmental benefits of using these recovered materials in their chosen applications.

2.2 Collaboration with local industries

The residues used in the assignments stem from local industry. The collaborating companies provided material to experiment and develop samples, did guided visits to their production facilities and gave feedback at the mid- and final term presentations.

To engage local industries, they are contacted by the course teachers to propose a collaboration. Joint meetings are held, in which examples of previous years' results are shown, after which the company presents a proposal for an innovation project in the field of IDE. The proposal is examined at the institution and based on the length and complexity of the proposal, determines the best format to execute it. All collaborations done for this assignment are framed as an Academic Project, i.e., to be developed as a real-world challenge within a regular academic course. Under this consideration, the parties jointly agree and develop a project brief, which outlines the objectives of the Academic Project and the elements and phases of its development, as well as the composition of the participating teachers and student teams. This document is the base for the collaboration contract to be signed.

Besides the Academic Project, our teaching institution has 3 other formats of collaboration with companies: the Innovation Lab (Part-time, extracurricular engagement, over a period of 8 to 15 weeks),

Thesis Projects (engagement of a group of students to develop their final thesis projects with the proposed challenge, for a period ranging between 5 to 8 months) and Industrial Doctorates (research developed by an industrial doctoral student, for a duration of 2-4 years). Intellectual and industrial property rights are agreed on a case-to-case basis.
During the years, this challenge has been presented with the collaboration of four local industries: two manufacturers from the textile sector, one provider of components to the automotive sector and one service-provider for industrial apparel cleaning. Their challenges and materials were all slightly different (summarized and anonymized to be included here):

1. **Waste fluff from industrial washing services.** This waste is made up of fibres that break off from textiles during washing, such as cotton, polyester, and other synthetic materials (image **b** in Figure 1). The fluff is often contaminated with detergents, fabric softeners, and other chemicals used during the washing process, making it challenging to dispose of. The company generates between 250-2500 tons of fluff per day. The aim is to design materials and necessary processes to transform the remaining fluff from industrial laundry filters into useful materials, reducing the environmental impact of the process.

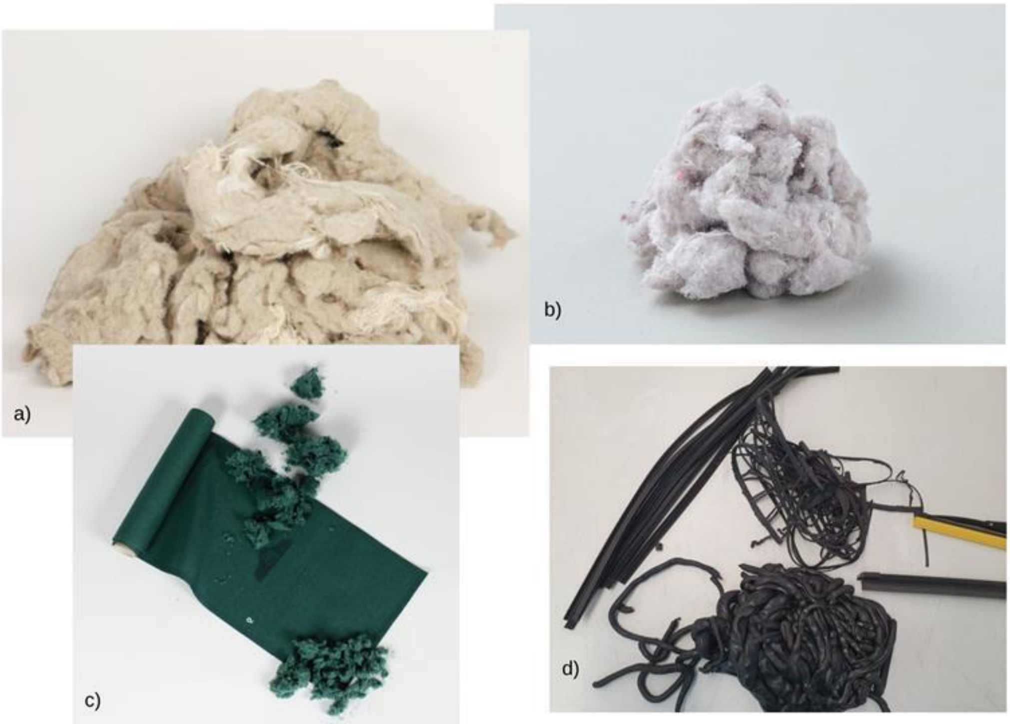

Figure 1. Samples of the waste materials used in the challenge: a) Spinning fibres, b) Laundry fluff, c) Textile cut-offs, and d) Rubber

2. **Waste fibres from a spinning mill.** The spinning mill is specialized in the production of thick yarns of 100% Cotton, 100% Linen, blends of Cotton/Linen, and blends of Cotton/Hemp Open End, with a capacity of 7,000 tons per year. Circa 25 tonnes of waste per year are generated, being the waste composed of fibres, threads, and hemp dust, with small amounts of cotton, released throughout the spinning process (image **a** in Figure 1). These fibres are too short to reuse in the spinning process. The project idea was to demonstrate the possibility of revaluing the organic waste through simple processes and assign possible uses and fields of application to the designed material.
3. **Fabric offcuts from a cotton cloth manufacturer.** Offcuts are the smaller pieces of fabric that are left over after the larger pieces are cut. Often, these offcuts are discarded as waste, contributing to the growing problem of textile waste landfills. The challenge was to explore ways to recycle or repurpose offcuts into new products that can be scalable for industrial production. These specific offcuts were a combination of cotton cloth impregnated with a thermoset polymeric resin and a total of 1 tonne per year are generated (image **c** in Figure 1).
4. **Rubber waste from a windshield wiper manufacturer.** Natural Rubber (NR) is a common material used in windshield wiper blades due to its elasticity and durability. However, the

production and disposal of NR waste can pose environmental challenges. The industrial waste is composed of vulcanized NR bits, followed by chlorinated rubber and, in smaller quantities, non-vulcanized rubber, generating a total of 16,3 tonnes of residue/year (image **d** in Figure 1). Students were asked to look for application areas within the automotive sector.

3 RESULTS

During the first 4 years, a total of 63 student groups (of 3-4 students) participated in this challenge. Of those 63, a selection was made of the projects that obtained high grades in both courses, resulting in 26 projects included in this review. Table 1 gives an overview of the student works included per challenge and how they were assessed. It is important to note that the company that provided the Spinning fibres did not give feedback to student work and during 2019-20, the study only includes the trimester that was not affected by the COVID pandemic.

Table 1. Overview chart of student work and its assessment as defined in section 2

Challenge	Year	# Groups	# Groups Reviewed	Assessed with 12 or more	Company selected	Company Feedback
Laundry fluff	2018-19	20	4	1	3	Yes
Spinning fibres	2019-20	10	5	1	-	No
Spinning fibres	2020-21	13	3	0	-	No
Textile offcuts	2020-21		5	1	3	Yes
Rubber	2021-22	20	9	2	1	Yes
Total	**2018-22**	**63**	**26**	**5**	**7**	**-**

Note that the best assessed works does not always coincide with the projects selected by the companies. In fact, 3 of the 5 projects that were evaluated with 12 points or higher (for the combined criteria of technical viability, material circularity and environmental impact), were selected by the collaborating companies. Of the remaining 2 well evaluated projects, one (with 12/15 points) was the best evaluated in the year when the company did not get involved in the feedback and did not have an interest in taking any of the proposals further, while the other (with 14/15 points) was the best evaluated last year, but the company selected the other well assessed project (with 12/15 points), probably because they worked with a more interesting market application. Each of the remaining four projects selected by the companies obtained a score of 11/15 points. Of all the projects, two have moved on to be further developed in an Innovation Lab collaboration. The following sections describe these best projects in some more detail, indicating next to the project name their corresponding challenge and the assessment score obtained.

3.1 Materials selected by the collaborating industries

- CLINT (Laundry fluff, 14/15) and CUNIU (Textile cut-offs, 13/15), were both selected to be developed further in an Innovation Lab (images **a** and **b** in Figure 2). Both materials contain 99% of the original waste and 1% additive. They use the highest amount of waste of all materials resulting from the challenge, with a simple industrialization process that uses the same manufacturing steps as cardboard, resulting in similar applications (e.g., business cards or packaging).
- PLAXTILE (Laundry fluff, 11/15) is polypropylene reinforced with laundry fluff (image **c** in Figure 2). It increases mechanical strength while the waste results in an interesting aesthetic of the final material, a texture that looks like marble. The manufacturing process is the same as that of current thermoplastics.
- TVÄTT (Laundry fluff, 11/15) only uses waste and gelatine that is a residue of the meat industry. It has interesting aesthetics, with a variety of colours for use in lamp screens in thin layers. In thicker versions, it can be a substitute for plasterboard (image **d** in Figure 2).

Figure 2. Selection of the best materials according to the collaborating industries: a) Clint, b) Cuniu, c) Plaxtile, d)Tvätt, e) Rinew, f) Cotech, and g) Scooter-Roll

- RINEW (Textile cut-offs, 11/15) uses waste from the rice industry mixed with crushed organic cotton waste (image **e** in Figure 2). The manufacturing process is easily scalable for industrial use, with potential applications in fashion industry labels or as material for 3D printing.
- COTECH (Textile cut-offs, 11/15) is a compound made from shredded cotton waste mixed with polycaprolactone (PCL) plastic (image **f** in Figure 2).
- SCOOTER-ROLL (Rubber, 12/15) is made of 50% waste and 50% PUR (polyurethane), which is its weakest point, as the amount of waste reused is only 50% (image **g** in Figure 2). However, it has a high added value application in electric scooter wheels that cannot be punctured given that they have no air chamber.

4 DISCUSSION AND CONCLUSIONS

After four years, of 180 students organized in 63 groups, 26 proposals were deemed interesting and rigorous enough to include in this review. Of those, only two proposed materials were developed further as Innovation Lab projects and were produced in a pilot test. Both materials were mostly composed of the waste provided by the company (99%) and had the support of the collaborating industry to pursue the exploration of the application suggested by the students. So, it seems that a significant factor of success is the interest the industrial partner has in the developed material. This corroborates literature findings that indicate that the main barrier to repurposing industrial waste is the lack of demand for the newly developed material/product [7]. This became evident in cases where the company provided the material and was not providing any feedback.

The challenge as it was presented to the students is quite ambitious, with several students commenting in class that they consider that the assignment is difficult, given that they are expected to develop a competitive material, with an application that added value. Despite the complexity of the challenge, the fact that there have been projects that succeeded in proposing something worthy of further development, speaks in favour of presenting upcycling tasks ambitiously in design education (as proposed by [8]). When the challenge was done with rubber waste, the collaborating company asked students to find applications within the automotive sector, as it would be more relevant to them. This additional requirement had pros and cons: Material applications were developed in greater detail, but with lower motivation and engagement from students. Having the material samples from the beginning of the courses helped students take a hands-on approach to material experimentation and design, making it easier to understand material properties and get actively involved in the challenge.

A commonly applied strategy in the different projects has been to develop hybrid materials, mixing organic and inorganic components. Although the resulting new materials may succeed in valorising existing industrial waste flows, the hybrid materials cannot be considered circular as, at least for now, they are neither recyclable nor compostable. The potential environmental benefits of the materials developed are remarkably influenced by the application defined for them. If used in other applications, these same materials could have higher or similar benefits, or on the contrary, a higher environmental footprint than existing materials. This is part of the learning outcomes that are expected by the course, but it is important to discuss, given that materials obtained from waste per sig are not necessarily more environmentally beneficial than other materials used for specific applications. Likewise, it is also noted that even if the proposals developed use waste materials, they are still expected to perform as well or better than the product they are compared to. This has been commented by designers working with industrial residue, who say that users expect the product to be cheap or suspect that it is of less quality if the product specifically indicates that it contains residue [10].

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FROM AN INDIVIDUAL TO THE INSTITUTE: A CASE OF 'MULTI-USER CENTRIC CODESIGN' APPROACH IN DESIGNING SOLUTIONS FOR CHILDREN WITH SPECIAL NEEDS IN RESOURCE-CONSTRAINT SETTINGS

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ABSTRACT
Design of specialised products, such as assistive devices, for users with special needs, such as children with disability, requires a holistic design as well as pedagogical approach. The designer/engineer is encouraged to take a Problem-based Learning approach with the intent to develop 5 top skills identified for industry-readiness and in turn, aid in developing learning objectives for each skill based on the design experience, that will be invaluable for the designer/engineer for designing specialised solutions (assistive/customisable devices) for special user groups (children with special needs), by leveraging systemic collaborations with multiple users, beyond the solo primary user/beneficiary group. This paper presents, the adoption of the co-design approach with multi-users, beyond the primary users, involved in the rehabilitation of children with special needs, and reports the reflections and insights of designer/engineer on the required learning (objectives) to design such specialised products that employs co-design / multi-user centric design process. Presently, these learning objectives are being implemented in design project course to evaluate its impact on the 5 top skills as learning outcomes.

Keywords: Product design, engineering, learning objectives. co design, assistive devices

1 INTRODUCTION
Assistive devices (ADs) and technologies are highly specialised solutions, as they heavily rely on domain and experiential knowledge of experts and users, that an engineer or product designer may not possess. Along with user involvement, interdisciplinary and transdisciplinary research is inevitable for the design of assistive devices, products, and technologies [1]. It is multi-faceted; where the medical aspect, the design aspect, and the integration of the two, determine the extent of successful usage of these products [2]. The challenge of designing ADs for children with special needs is further compounded as the children, i.e., the primary users; are incapable of providing user needs and requirements, which are very critical in these devices [3,4]. Limitations related to language usage, literacy, and variation in cognitive development to communicate ideas can pose as a further hurdle in designing such solutions with children as co-design participants [5]. So, while designers and engineers have the innate ability to undertake the required research – secondary and primary, to define technical and market needs, they face difficulties in defining the user needs, as well as incorporating the user feedback, in spite of employing co-design, due to the above mentioned issues. Therefore, there is value in educating them on ; (i) identification and prioritisation/ categorisation of the multiple users involved in design of specialised medical devices for special needs groups, and (ii) the appropriate or potential of co-design, but extended so as to accommodate important users and expert individuals and institutions, such as, therapists, rehabilitation professionals and rehabilitation centres, who are capable of being sound design partners and custodians of the beneficiary or primary user, i.e., children with disability.
The Problem-based Learning (PBL) perspective, which is known to be fruitful in developing key skills in designers and engineers, such as, critical thinking, problem solving, communication, collaboration and self-learning [6], was employed to deliver a design-based project course with the development of these skills as learning outcome. A design exercise was undertaken, beginning with identification of

real-world problems faced by children with motor impairments and designing a customisable assistive device for them through co-design. During this exercise, it was empirically found that designers benefitted from adopting the multi-user centric approach, which extends co-design, from an individual, i.e., the primary user, to multiple users, i.e., the members and the institute.

2 BACKGROUND LITERATURE

New levels of expertise and interdisciplinary methods are required to incorporate appropriate levels of knowledge and skills from all stakeholders to develop ADs [1] and hence, a pedagogical intervention has value. ADs play a prominent role in the rehabilitation of people with disabilities, as using these along with available treatment procedures help people with disabilities achieve independent and dignified living [1]. Rehabilitation is crucial to enable the functional ability of children with motor impairment [7]. Evidence from the literature further emphasises that ADs are preferably customised to suit the local context, therapeutic requirements, and user environment [8,9] and that rehabilitation professionals/therapists look for means to customise these products to fit the patients. The therapy sessions (physiotherapy) and activities are vigorous and often uninteresting to children, however, employing ADs during these sessions can make them engrossed in the activities [2]. Along with the caregiver, the rehabilitation professionals/therapists are key stakeholders in the use phase of the ADs and may, in certain cases, also be users [7]. They are the main facilitators of ADs to end users/beneficiaries and implicitly influence the choice, adoption, and regular usage of ADs by the patients [10]. Their knowledge of functional implications, biological aspects, therapeutic requirements of disability, etc. is paramount in defining user needs for ADs [10], and they can also mitigate the circumstances during the design process due to their standing with the primary user, the child beneficiary. Therefore, they are not only secondary users, but also proxy for the primary user. However, while direct communication between designers and users helps in a better understanding of the problem domain and facilitates the elucidation of relevant design parameters within the design process [11], the engineers and designers are not educated in “how to” mitigate such special needs circumstances. Understanding the nuances of the use case and user environment for the design of ADs beckons the involvement of users and caregivers in defining the same, in turn, aiding the designer/engineer to incorporate social, emotional, and cultural aspects of user contexts [12]. In addition to this, factors like recruiting participants, especially children, and their caregivers in the entire design process and not just during the later stages of validation can be challenging for the design team. Further, building the connection with the caregivers and the children, time consumed during data collection, children’s attention span during the process, and children’s cooperation can be hurdles in the design process [12]. Thus, several learnings are required on the part of the designer/engineer to enable the design of ADs, that too for users with special needs.

In the instances where the experience and knowledge of the user on a specific domain becomes critical, the user participates in the design process as the co-designer. The products or interventions that have multiple users or require interactions between multiple users and require interdisciplinary expertise from multiple stakeholders, need the understanding of all the stakeholders, leading to a multi-user centred design approach [13]. These are characteristic of co-design, and while there is strong evidence from earlier works [2,3,10,13] regarding the adoption of this approach in the design of ADs, there exist lacunae in what capacities or the extent of involvement and role of various stakeholders in these approaches. Therefore, by extending the co-design approach to ‘multi-user centric’ enables the multi-users to partner in the design process, not only as experts and secondary users but also as proxies.

This holistic approach has been used as a learning environment to pursue the development of the 5 top skills (learning outcome) and in turn, identify the specific learning objectives required by designers and engineers for the design of ADs for special needs groups.

3 MULTI-USER CENTRIC CO-DESIGN PROCESS

The below presented design exercise undertaken as part of the ‘Design-based project’ course wherein the objective was to identify a ‘wicked’ problem and design a specialised solution for a special needs group. Based on the area of interest, the designer/engineer chose the design of a customisable assistive device in resource-constraint settings and explored multi-user centric design approach. This section describes the design process followed, and reports the reflections and insights of the team on the design as well as the learning outcomes of the design process ;

The design process began with the identification of a rehabilitation institute/centre to undertake a habitat study, through observation of therapy sessions. Training of hand skills was identified as a major opportunity area, upon corroboration with the rehabilitation professionals. A design aid for supporting hand skills training, involving the actions linked to "Touch", "Rotate" and "Press" was arrived at on the basis of the therapeutic requirements of the children in the institution, with the key motive to increase the engagement and participation of the children during rigorous and repeated training sessions. A gamified approach in training these skills was conceptualised.

A 'board game' was devised which operated as follows: An auditory stimulus is triggered to indicate the child to begin the game. The child has to progress through the different junctures of the game, beginning from the "start" point up to, the "finish" point using these actions - touch, rotate, or press (Fig. 1a). There is a reinforcement in form of green light for every 'expected action' (either touch, rotate, or press) of the child as per the requirement of the game. The reinforcement light also acts as a guide to help the child move to the next stage in the playground. A simple prototype to establish the concept (Fig. 1b). was developed, using rapid prototyping techniques. Provision to include fixtures based on the specific needs of the children to enable customisation was also provided. Feedback on the concept and prototype, obtained from the rehabilitation professionals, established that the concept was usable, appealing to the children and was designed based on the local context and requirements of the children and the institute.

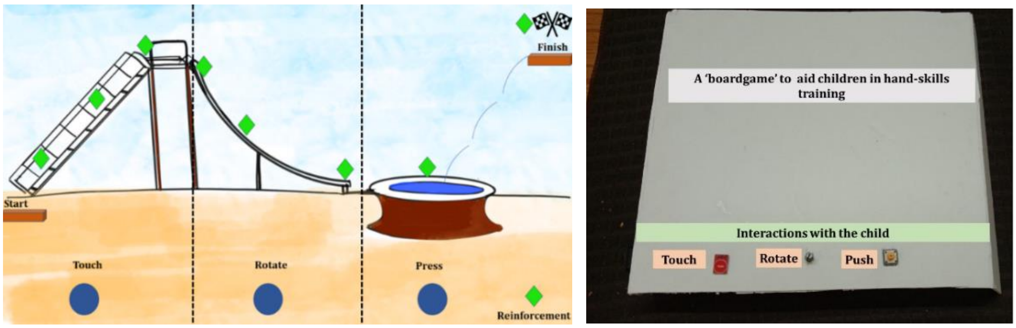

Figure 1. Finalised concept ((a): illustration of the concept, (b): embodiment of the board game

Leveraging the experience of the design team in this process, engagement of the multi-users for the co-design and development of assistive devices, may be described in 3 phases, as illustrated in Figure 2.

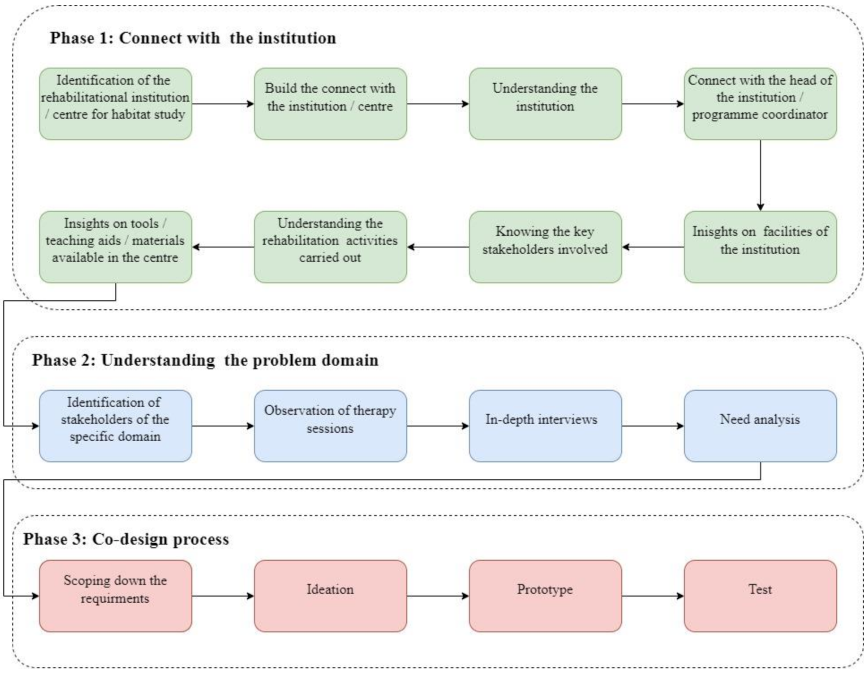

Figure 2. A diagrammatic process flow of 'multi-user centric' co-design approach

4 DISCUSSIONS

4.1 Reflections and Insights from the designers

Following are the reflections and insights of the design team on the multiple-user centric, co-design approach for design of a customisable assistive device for children with motor impairments;

- A key insight is that the rehabilitation institution/ centre, along with its physical and human resources, behaves as a one-stop solution for understanding the problem space and serves as an active ground for testing and iteration. It also saves time in the overall design process, helps build trust among the other stakeholders, and promotes easier acceptance and adoption of the designed intervention.
  - *"Interactions with the institute's program coordinator helped in knowing its functioning, facilities, activities undertaken, etc. Further discussions highlighted different stakeholders, involved in the institute, their roles, and responsibilities in the rehabilitation / therapeutic activities. This was better understood with the observation of therapy/training sessions, and familiarity with existing assistive devices and tools which aid in these sessions were also understood."*
  - *"Although the children are the direct beneficiaries of any assistive devices used during therapy sessions, the other stakeholders are users of these devices as well, and their needs, and ability to bridge and elucidate the needs of the children, is very critical in the successful adoption of assistive devices. This was clearly established during the observations and interaction sessions while designing the aid."*
- The evident insight was that, enabling the multi-users (rehabilitation professionals, caregivers, and the institute itself) in taking design decisions, encouraged them to convey their requirements as users and facilitators of assistive devices during sessions, which would not have been captured exclusively otherwise. Further, involving the multi-users, not just for the usability testing, but also at various stages including, but not limited to; elucidation of needs, understanding the problem space, generating technical requirements, scoping down the target, concept generation, prototyping, etc. resulted in a usable, user-friendly design solution, which is appropriate to the local context, as per the expert feedback obtained.
  - *"Adopting rapid prototyping tools and techniques helped in building proof-of-concepts to communicate ideas among the different users involved, and also, to include features that facilitated customisation."*
  - *"Another important learning was the mode of communication and exchange of ideas, and concepts between the design team and the other stakeholders. Real-life images and illustrations proved effective in communicating and exchanging ideas with non-designer partners (rehabilitation professionals, parents, etc.) in the process of co-design over sketch-based illustrations."*
  - *"Due to prompt involvement, quicker iteration cycles of prototyping could be undertaken, and multiple functional versions of the prototypes could be developed and tested with the users and proved to be better in comparison to testing of mock-ups or sketches."*
- A profound insight received was that the multi-users have a common understanding of the target audience. Beyond eliciting requirements and affirming the needs of children, feedback on the prototype from these multi-users proved to have high coherence. This paved the way for; exploring scenarios to extend the use of the same aid to other users or target groups and understanding new requirements from other groups within the same system.
  - *"In addition, exchanging ideas and expertise among different design participants, i.e., the designer/engineers and rehabilitation community, strengthened the collaboration which paved the path for future work between the same teams."*

.

4.2 Learning objectives and outcomes

The design-based project, used as the learning environment for engineers and product designers in the area of design of specialised products, such as, assistive devices for special needs groups, helped identify the various challenges discussed above and in turn, below mentioned learning objectives pedagogical support to incorporate the top 5 skills for Problem-Based Learning.

The following learning objectives have been outlined and are presently being practically implemented in the project course;

- ***Critical Thinking:*** To engage with multi-users and at the instructional level, beyond the user/individual, so as to receive and develop critique and analytical take-always on the situation;

- ***Problem solving:*** To enable multi-users with design decisions and in the equitable role as co-designers and participants, beyond being experts, testers, and feedback providers;
- ***Communication:*** To visit frequently and observe sessions, and be involved in continuous conversation to analyse, evaluate as well as convey design intentions for being on the same page;
- ***Collaboration:*** To leverage institution to garner trust and to imbibe onus in each user type as design participant on behalf of the beneficiary, but also oneself as an important user;
- ***Self-learning:*** To lean on the expertise of expert users as well as one's primary research experience to learn about the design situation and participants, prior to as well as throughout the co-design process.

5 SUMMARY, CONCLUSIONS & FUTURE WORK

This paper explores the nuances of 'multi-user centric' co-design approach by engaging with multiple users, i.e., a rehabilitation institution/ centre and its professionals, to design a specialised solution as an assistive device for a special needs group, i.e., children with disability, more specifically, motor impairment. A customisable assistive device to train hand skills was conceptualised and a prototype to establish proof of concept was developed with participation of the multiple users. Feedback from them - institute programme coordinator, special educator, etc., on the overarching concept and initial prototype, indicated that the device could be extended to other target audiences as well. The reflections of the design team on various aspects of the design process, including challenges faced, and benefits of engaging with multi-users is presented in this work, based on which learning objectives are mapped to desired outcomes (top 5 skills) for engineers and product designers, so that they may leverage these in designing solutions for special needs and in turn, inculcate the desired skills of industry readiness. Presently, the set out learning objectives are being implemented in the design project course to evaluate its impact on learning outcomes and the quality of design outcomes, with the intent to develop a holistic pedagogical support.

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RESOLVING LANGUAGE BARRIERS WITHIN THE CONTEXT OF GLOBAL CO-HABITATION, WITH NEW EDUCATIONAL SUPPORT STRATEGIES FOR RESPONSIBLE INNOVATION

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ABSTRACT
This paper focuses on resolving language barriers within the context of co-habitation for displaced communities, specifically between immigrant parents and Turkish teachers within the Turkish education system. Syrian immigrant parents are the majority of immigrants in Türkiye, and they struggle to play a role in their children's education because of language problems which negatively affects immigrant students' success as well as the welfare of the community over the long term. This paper offers a framework of parameters for Human Centred Design and Information Design, in addition to new educational support strategies, methods and mentoring, which can be relied upon to help students and graduates address current and future challenges for responsible innovation. The paper will expand on the detailed findings that Syrian parents and local teachers might not be able to maintain a dialogue due to language limitations, negatively affecting the success of Syrian students. Hence, this paper proposes an analysis of language barriers between Syrian parents and Turkish teachers including literature review and case studies. It has been reported that language barriers extend beyond language limitations, to other factors associated with 'unfamiliarity with the issue', 'emotional barriers', 'cultural differences', and 'personal features' according to context, which benefits from a design-led multi-perspective approach.

Keywords: Language barriers, immigrant parent-local teacher communication, global co-habitation, human-centred design, information design

1 INTRODUCTION
This paper will discuss preliminary results of the doctoral study, which aims to develop design guidelines for Turkish school management teams to reduce language barriers between local primary school teachers and immigrant parents to help co-habitation for displaced communities. The research is divided into 3 years. The first year focused on literature review and case studies. The second year will concentrate on primary research with key stakeholders and data analysis. Finally, the last year will be dedicated to the development of guidelines and practical solutions (see Table 1). In this paper, key results from literature review and case studies will be discussed. The goal was to develop an in-depth understanding of reasons contributing to language barriers between Turkish primary school teachers and immigrant parents. In this way, suitable design approaches can be selected to address these issues appropriately.

Table 1. Processes of the PhD research

Year 1	Year 2	Year 3
Literature review & case studies: Immigrant situations in Turkey (focusing on primary school context)	Interviews with key stakeholders: immigrant parents, primary school teachers and school management	Data analysis using qualitative tools (such as thematic analysis) in order to extract key themes
Literature review & case studies: design theories (HCD, information design, etc.)	Interviews with experts in relevant fields: information design, human-centred design, etc.	Develop guidelines and practical solutions for Turkish primary school management based on key themes
Literature review & case studies: language barriers in the school context and other sectors	Card sorting to find out preferences of key stakeholders regarding existing solutions, e.g., interpreters	Evaluate the guidelines and practical solutions with key stakeholders, e.g., school management

1.1 The rationale behind the study

In 2013, Syrian immigrants started to migrate to Türkiye because of the war in Syria. According to the Turkish Immigration Administration (2022), there are currently 3,76 million Syrians who are the majority of the immigrants living within Turkish borders. The Turkish context shows that these people are unable to integrate into the local community mainly because of language barriers (Akar and Erdoğdu, 2019) since the language problem is associated with other problems they are often encountered which can be explained with Maslow's hierarchy of needs.

Maslow divided people's needs into five groups and illustrated them in a pyramid to prioritise these requirements. These are 1) physiological needs; 2) safety needs; 3) belongingness and love needs; 4) esteem needs; and 5) self-actualization needs. According to his theory, people must meet basic needs to survive. The psychological needs category follows basic requirements, which covers intimate relationships and friends. The last one is self-fulfilment needs, which focuses on achieving full potential of a person as illustrated in Figure 1. Syrian immigrants could not meet their basic requirements, as they cannot easily find jobs which leads to financial problems. Thus, they encounter difficulties buying food, paying for rent and bills, among other costs. Finding a job is especially challenging for people who cannot speak the local language (Jamil et al., 2012). Those people also generally have problems socialising with their neighbours and other people around them due to language barriers. As a result, they usually are not able to meet their psychological requirements either. Due to the language barriers, Syrian immigrants are not able to integrate into the community (Akar and Erdoğdu, 2019; Vesek, 2021) and struggle with various issues. Although education has great effects on communities (Hjalmarsson and Lochner, 2012), this research focuses on the educational side of their problems.

Education is one of the most important issues for communities since developed societies give great importance to education although the welfare level of the region is related to the quantity of educated people in the community. Hjalmarsson and Lochner (2012) reported that educated communities have lower crime rates. In this sense, education helps communities to have more peaceful lifestyles. Moreover, educated communities reach better economic conditions over time (Barro, 2001). Qualified workers create value in work areas, which helps nations to reach higher economic levels. Consequently, the countries become less dependent on other nations (ibid). With regard to this, governments should improve education of communities in terms of having a better standard of living. Parents play a crucial role in education. Parental involvement often has positive effects on students' success (Alper and Yıldız, 2015; Đurišić and Bunijevac, 2017), especially in primary school levels and hence, parent teacher communication needs to be improved. This project focuses on communication between immigrant parents and local primary school teachers in Turkish school which can help welfare of the Turkish community in a long-term plan.

1.2 Research approaches which can help the research problem

This research covers human and communication issues, which require a Human-Centred Approach and suitable means to help both parties communicate. The design approach frames the whole research project and ensures an in-depth understanding of other factors which directly or indirectly affect existing problems. In this case, the researcher will involve different stakeholders including teachers, parents, the school management team, and the interpreter service team to gain a different variety of views. Information Design principles often facilitate the conveying of information to others in a clear way (Black et al., 2017-see Section 5.2), so the principles can be useful for the guideline which are aimed to be given to school management teams.

2 BACKGROUND RESEARCH

Examining the context, there is a large group of studies for language barriers in healthcare services but usually not in schools. Regarding the Turkish context, there is no in depth examination and solution for language barriers which can help immigrant parent-Turkish teacher communication so this research will be a unique study to help parent-teacher communication, especially in Türkiye. The nature of language requires an in-depth understanding, and this paper will mostly focus on key factors accompanying language barriers.

3 AIM AND OBJECTIVES

The aim of the paper is to have an in-depth understanding of factors contributing to language barriers, and address language barriers between immigrant parents and local teachers to decrease the impact of language barriers in Turkish schools. The objectives are given as follows:

1. To explore language barriers within the context of co-habitation for displaced communities, specifically between Syrian immigrant parents and local teachers within the Turkish education system
2. To examine how Human-Centred Design and Information Design principals could help this project.
3. To introduce new educational support strategy for responsible innovation-offering a guideline for school management team which can help reduce language barriers between teachers and immigrant parents.

4 METHOD

Firstly, the researcher carried out a literature review to have a better understanding of problems of Syrian immigrants in Türkiye (see Inclusion & exclusion criteria for literature review in Table 2) and found out that language barriers are the main factor behind most of their challenges. After deciding focus on the educational side of their problems (see Section 2 and 3), she examined case studies to have an in-depth understanding of factors affecting immigrant parent-teacher communication in Türkiye (see inclusion & exclusion criteria for the case studies in Table 3). Meanwhile, she examined language barriers context, factors contributing these barriers (see Section 7.1). Finally, the researcher shows how other factors contribute to language barriers between the two parties (see Section 7.2), and discusses which factors need to be taken into account for the solution phase (see Section 8).

Table 2. Inclusion & exclusion criteria for literature review based on problems for immigrants in Türkiye

Inclusion criteria	Exclusion criteria
Recent reports of the Turkish Government focus on problems of Syrian immigrants	○ The reports which are not recent ○ The reports which examine problems of other minority groups
Recent research from the Turkish context focuses on Syrian immigrants	○ The papers which do not cover the last 10 years. ○ The papers which focus on other immigrant groups
Updated information from official websites related to Syrian immigrants: Republic of Türkiye Ministry of Interior Presidency of Migration Management (goc.gov.tr), official charities based on Türkiye (e.g., multeciler.org.tr), Turkish newspapers & journals	○ Information which is not recent/updated ○ Information which does not focus on Syrian immigrants. ○ Sources which are not based on Türkiye.

Table 3. Inclusion & exclusion criteria for case studies based on problems for immigrant parents and Turkish teachers

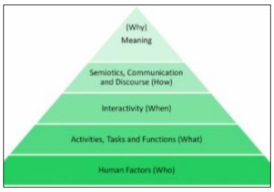
Inclusion criteria	Exclusion criteria
The examples focus on examining language barriers between immigrant parents and local teachers in Türkiye	The examples focus on different problems of immigrants in Türkiye in other contexts
The studies based on primary education	The studies based on other education levels (e.g., kindergarten, middle school, high school)
The examples include primary data from local teachers and/or immigrant parents	The examples which do not include primary data from Turkish teachers and/or immigrant parents

5 DESIGN APPROACHES WHICH CAN HELP LANGUAGE BARRIERS

5.1 Human-Centred Design (HCD)

The HCD approach has been referred to as a theory for considering users as well as their environments in the design process (Giacomin, 2014, IDEO, 2015). The design approach has often been used to solve human problems. There is HCD pyramid offered by Giacomin (2014) – see Table 4, which could be applied to various design processes. The triangular pyramid includes five phases from the bottom to the top: 1) human factors (who); 2) activities-tasks and functions (what); 3) interactivity (when); 4) semiotics-communication and discourse (how); and 5) meaning (why). The question in the top of the pyramid could be useful in terms of explaining reasons for developing new solutions while the following steps could be used to create solutions. In this project, HCD principles offered by Giacomin (2014) are followed, so the pyramid can be addresses based on this research (see Table 4).

Table 4. The Human-Centred Design pyramid (Giacomin, 2014) and use of HCD in this project

<table>
<tr><td rowspan="5">
</td><td>Meaning (Why)</td><td>To help immigrant children's achievement, and welfare of the local community in a long-term plan (see Section 2)</td></tr>
<tr><td>Semiotics, Communication and Discourse (How)</td><td>With the help of Information Design Principles (see Section 5.2)</td></tr>
<tr><td>Interactivity (When)</td><td>Parental meetings</td></tr>
<tr><td>Activities, Tasks and Functions (What)</td><td>To help parent-teacher communication</td></tr>
<tr><td>Human Factors (Who)</td><td>School Management Team, Turkish primary school teachers, immigrant parents, interpreter staff</td></tr>
</table>

The importance of this research can be an explanation for the *'Meaning'* (see Section 1.1) while the principles of the Information Design can be useful for developing a solution (see Section 5.2), which can help integration of immigrant parents in Turkish schools. The human factors are not only immigrant parents and Turkish teachers, but also other staff related to this problem. The school management team can be advised to offer a guideline to reduce the language barriers between teachers and parents. In this case, interpreter services will be a crucial part of the solution.

5.2 Information Design

Information design is referred to as a 'visual function' which means avoiding confusions in daily lives by offering correct directions to people for having more comfortable daily experiences (for example, designing road maps in a clear way) (Petterson, 2002, Black et al., 2017). Recently, it has often been applied to deliver complex information in a clear way in various areas (Waller, 2011).

There are some principles of Information Design which have been applied by designers to convey information clearly (for example, Gestalt principles). Such theoretical information has guided designers to generate the whole Information Design process. Besides this, there are practical ways to facilitate converting information to others. Although school managers tend to communicate with parents using written format documents, Information Design principles can be useful to convey information from school management team to immigrant parents clearly.

6 FACTORS CONTRIBUTING TO LANGUAGE BARRIERS BETWEEN THE TWO PARTIES

In this section, the parameters of the language barriers (Section 7.1), and their effects on immigrant parents-Turkish teachers are explained (Section 7.2).

6.1 Key factors should be considered within language barriers

Differences in communication types can create emotional barriers between people, as well as unfamiliarity with issues, and personal features of each individual (Zhong and Zhou, 2011; Kapur, 2018) - see the explanations below:

Cultural differences in communication types: Cultural differences are the diverse behaviours, beliefs, traditions, customs, and expressions that are characteristic to groups of people of a specific race, ethnicity or national origin (Moran et al., 2014: 11-15). Cultural differences between people can affect the mode of communication with each other (Moran et al., 2014: 38-66).

Emotional barriers: Kapur (2018) defines emotional barriers as positives and negatives which are happiness, anger, frustration, stress, depression, anxiety, trauma, and pride. Researchers have reported that emotional issues affect engagement among people. People can express themselves more efficiently when they feel comfortable. In contrast, when people feel highly stressed during conversations, they might not understand others well; they could miss some part of narratives, or they could misunderstand (ibid).

Unfamiliarity with an issue: Unfamiliarity with a subject has been defined as the fact of having no knowledge or experience of the area. Differences of understanding and definition for the same point are also part of this challenge. People struggle with understating issues when they are not familiar with the topic/phrases (Kai, 2005).

Personal features: Personal characteristics are aspects of personality, experience, talents, competences, and social status which could be used to describe a person (Subedi, 2020). Some features which could define a person include being calm, shy, outgoing, warm, practical, approachable, balanced, helpful, and kind. Such personal features are effective in social communications, for example, people could feel more comfortable to ask for help from people who are kind, and approachable. Similarly, outgoing people could express themselves more clearly compared to those who are low in self-confidence (Joinson, 2004).

6.2 Language barriers between the two parties, displaced and local communities-immigrant parents and Turkish primary school teachers

The Turkish context shows that language is the main reason behind parent-teacher communication in Turkish schools. Besides this, there are also other factors accompanying this problem due to emotional issues, cultural varieties, and being unfamiliar with the local education system (Akar and Erdoğdu, 2019; Tumkaya and Copur, 2020; Vesek, 2021) – see explanations below:

- **Emotional barriers between the parents and Turkish teachers:** Integrating Syrian immigrants presents a number of challenges to the local community. Following this, it can lead to immigrants not fully sharing their needs and feelings within the new community, and this can be more difficult when people hold different beliefs about each other, such as with immigrant parents and local teachers.
- **Cultural differences between Turks and Syrians:** There are a number of cultural differences between the two groups. For example, Syrians have traditional lifestyles where the power of authority is much more visible while Turks are more likely to be between modern and traditional lifestyles which could affect the method of communication between teachers and parents. In Türkiye, parents and teachers usually meet privately in order to co-operate for the existing problems. However, in traditional communities, teachers are more likely to hold power on themselves rather than co-operate with parents. Following this, they are not expected to carry out regular dialogues with teachers. Consequently, the immigrant parents may not know how to get in touch with teachers, and to know at what level to make contact. As a result, differences in communication styles between parents and teachers in the two countries could prevent effective communication between local teachers and the immigrant parents.
- **Unfamiliarity of Syrian parents with the Turkish education System:** Most countries have their unique education system (for example, acceptance to schools, evaluation criteria in exams, education terms and breaks, expectation from students and parents). With regard to this, the immigrant parents may not understand some of the local educational terms in a new country. Following this, integrating immigrants into the Turkish systems could be challenging for Syrians as well.
- **Personal features:** All individuals have different characteristic features, which may affect the method of communication. In this case, it may not be practical to differentiate personal features based on the two groups.

7 DISCUSSIONS

Although a school management team has the authority, management staff can help to manage language barriers effectively between immigrant parents and local teachers. Therefore, a guideline for management teams can be beneficial to manage the situation. HCD and Information Design principles can help design the guideline (see Section 5.1 and 5.2) which can be developed based on the key factors accompanying language barriers between the two parties (see Section 7). In this case, emotional barriers between the teachers and parents, cultural differences between local and host communities, and unfamiliarity of being the local education system need to be considered. However, each person has unique personalities; therefore, considering personal features of each may not be possible-see Table 5.

Table 5. Discussion of the key factors of the language barriers for the research group

Key factors	Explanations	Inclusion/ Exclusion
Emotional barriers	The Turkish context shows that Syrian parents hesitate to communicate with local teachers which may result in emotional barriers that can prevent effective parent-teacher communication. Following this, resolving emotional barriers between the two parties can help reduce language barriers, and efficient parent-teacher communication.	Included
Cultural differences in communication	It has been reported that cultural differences between the two groups causes problems for the immigrant parents. In this case, resolving cultural barriers can help parent teacher communication. Following this, explaining the mode of parent-teacher	Included

types between Turks and Syrians	communication in Turkish education system can be beneficial in terms of reducing language barriers due to cultural differences.	
Unfamiliarity of Syrian parents with the Turkish education System	Unfamiliarity with the Turkish education system has been reported as one of the problems preventing parental involvement. In this case, delivering information to the parents about the Turkish education system and scope of parental meetings can be helpful.	Included
Personal features	Although individuals have different characteristic features which may affect the method of communication, it is not useful or practical to consider people's own characteristic features in a scientific study.	Excluded

8 CONCLUSION & FUTURE STUDIES

The language barrier is the most important problem for immigrant parents in Türkiye. The parents cannot be involved in the education of their children, which is highly important for their success. Besides language problems, emotional issues between teachers and parents, cultural differences between the two groups, and unfamiliarity of the Turkish education system also accompany language barriers. It has been declared that Human-Centred Design and Information Design principles can help with this problem. While Human Centred-Design principles can help framing this research, Information Design can be used in a solution phase to convey information clearly. A guideline for Turkish primary school management team can be generated based on the key factors contributing to language barriers with the help of Information Design principles. The guideline could help management teams provide a clear direction to interpreter staff, local teachers and immigrant parents in order to reduce language barriers and involve immigrant parents in local education areas. The factors identified through the literature review and case studies will be investigated further through suitable primary research. In this way, the researcher can confirm and prioritise them accordingly.

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MIND THE GAP: THE OUTCOME MAP AS A BRIDGE FROM SYSTEMIC SENSEMAKING TO PSS DESIGN IN A CASE STUDY ABOUT CHILDREN WITH INCARCERATED PARENTS

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ABSTRACT
Children of prisoners are often referred to as orphans of justice or forgotten children. These children are unheard and unseen in a world made by adults for adults, they are reliant on their environment. To be able to design for these children, the whole system of actors and actants around them should be included and addressed. Systemic design is a design approach to tackle this social issue. It provides insights into the complexity of the context. However, after mapping the context, the major challenge lies in translating the output toward a design solution. This paper proposes an approach to address complex design challenges by applying both systemic design and product-service system (PSS) design and using outcome mapping to facilitate the translation from systemic analysis to PSS design. The process is applied to a project supporting children with incarcerated parents as a case study. Systemic design is used to understand the complexity of the issue, while PSS design applies systemic insights to design a concrete and integrated product-service system. The paper contributes to the design field by evaluating outcome mapping as a possible bridge between the analysis phase and the idea generation phase of socio-technical issues.

1 INTRODUCTION
According to an estimate by Children of Prisoners Europe [1], there are 2.1 million children in Europe with a parent in detention. Despite this alarming number, children of prisoners remain invisible to the general public. Children of Prisoners Europe describes a child with an incarcerated parent as a double victim. Beyond the loss of a parent, these children face stigmatization, trauma, and stress. Children of prisoners are innocent but carry the sentence too. The effects of parental detention impact the emotional well-being, physical well-being, and personal development of the child. They are three times more likely to develop mental health problems, and five times more likely to be imprisoned than other children [1]. The impact of these children on society is underestimated.

Research [2], [3] shows that a good relationship between the child and the incarcerated parent results in less recidivism. So, by supporting and guiding children with imprisoned parents, the number of prisoners will decrease in the long run, the mental health will increase, and the amount of recidivism will decrease because children and parents are taken into account. The government stands to make considerable financial savings from reduced expenditure on mental health care, prisoners, and prison overcrowding. Further, society will benefit from less criminality, more inclusivity, and more social contribution.

On the one hand, this paper reports on a design research project that applies a systemic design approach to tackle social issues, providing insight into the complexity of the context. On the other hand, after mapping the context, the major challenge lies in translating the output towards a design solution, in order to shape a product-service system that empowers children with imprisoned parents. Thus, obtaining autonomy for children with incarcerated parents based on the levers of trauma, attachment, and resilience [4]. The paper focuses on the transition from systemic sensemaking to the design of a product-service system by employing an outcome map, allowing the designer to advance from the analysis to the possibility space. The design-inclusive research adopts a process to serve as a case study aimed at supporting the children of prisoners. Qualitative research was applied to understand the context of children with imprisoned parents in the analysis phase. The data collection methods supporting this research are literature research, observations, in-depth interviews with psychologists and prison staff, cultural probes, brainstorming sessions, focus groups, and user tests. This paper contributes to the design field by evaluating outcome mapping as a possible bridge between analysis and idea generation.

2 METHOD

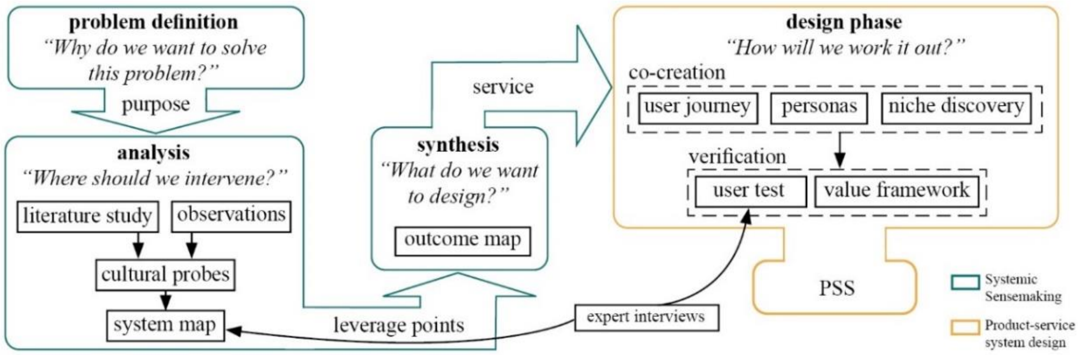

Figure 1. Approach of the design project

The design project consists of four main phases: the problem definition, the analysis, the synthesis, and the design phase (Fig. 1). The analysis determines where to intervene in the complex system and the synthesis, through outcome mapping, determines how to intervene in the system. Together they form the systemic sensemaking. Whereas the design phase uses the methods of product-service system design. The qualitative data collection methods supporting this research are discussed below. The prison of Hasselt, Belgium, is the main location for the data collection. Executing research in prison is a strenuous task. Not only does it take a serious effort to arrange a gathering in prison itself, but the prison system also imposes countless restrictions. For instance, electronics, such as phones and laptops, are forbidden. Therefore, all data is collected manually. As a result, the reporting is not a detailed account, but rather a summary of the insights from the various qualitative methods. To verify the reliability, several in-depth interviews are conducted with psychologists and prison staff.

The data collection methods are divided into three groups: the analysis, the design, and the verification methods. The first category includes a literature study, participant observations, and explorative expert interviews. The literature covers the topics of children with incarcerated parents, the Belgian prison system, and pre-existing prison initiatives. Through participant observations, the designer integrates with the prison environment for a period of 8 months during the weekly children's visits in Hasselt prison. The long-term period is important to reduce first impressions, and biases and limit time sensitivities [5]. During this period, conversations are held with an estimated thirty children and sixty adults, including (incarcerated) parents, family members, and prison staff. Interviews are executed with experts in the health care and prison sector to gain a better understanding of the context.

The design methods used are co-creation and a focus group. The prison system is an overwhelming context, especially for children. Gielen [6], [7] emphasizes that involving children in the design process gives them a feeling of control, which helps children to handle overwhelming situations. During this project, children are design partners. These children are the experts in their experiences, while the designer is the expert in the innovation process [8], [9]. The design team consists of a designer and two eight-year-olds. Besides the permanent team, about ten other children were consulted monthly to assist with decision-making. The focus group consists of six imprisoned fathers. The aim is to unravel their perspective on parental incarceration through motivations, obstacles, concerns, and expectations.

The third group of methods verifies decisions and prototypes during the process. The user test, performed by two children and their incarcerated parents over the course of one day in Hasselt prison, evaluates the user experience of the PSS and the functionality of the interactions of the product. It should be noted that no longitudinal simulation has been conducted, due to a lack of resources. Users indicated the user test was necessary to fully comprehend all the features and possibilities of the PSS. Although some confusion was encountered with the interface, the key feedback is that both children and parents were elated about the child's ability to take control of their relationship. To minimize subjectivity and bias experts are consulted to discuss insights, prototypes, and implementation. Examples of these experts are a family detention counsellor, a child therapist, an educator, the network managers of the prison in Hasselt and Beveren, the prison warden, and the policy coordinator.

3 SYSTEMIC SENSEMAKING

After the broad purpose definition to support children with an incarcerated parent, multiple analyses were performed to deepen the understanding of the topic. However, processing all this new knowledge requires a certain structure and approach. Therefore, the systemic design methodology, including causal

loop diagrams and the outcome map, is used as a way of sensemaking [10]. “Systemic sensemaking is the ability to recognize and understand complex patterns of relationships and interactions within and between systems, and to use this understanding to make informed decisions and take effective action.” [11]. For this case study the goal is to uncover interrelationships and emergent behaviours regarding the impact of incarceration on children with an incarcerated parent and to identify the leverage points that will form the DNA of the future product-service system.
The analysis phase uncovers several insights. For example, children of prisoners do not have the opportunity to avail their rights, they feel powerless and unheard by the adults surrounding them, and there is a lack of information toward children in all layers of the system. Further, a strong connection was found between the psychological concepts of trauma, attachment, and resilience. The detention of a parent is considered an Adverse Childhood Experience (ACE) [12], [13]. An ACE can lead to trauma, but also harms the attachment relationships and resilience of a child. According to Felitti et al., [12] there is an association between exposure to ACEs and negative health and behavioural outcomes later in life. The insights from the analyses are the input for systemic sensemaking.

3.1 Causal Loop Diagram

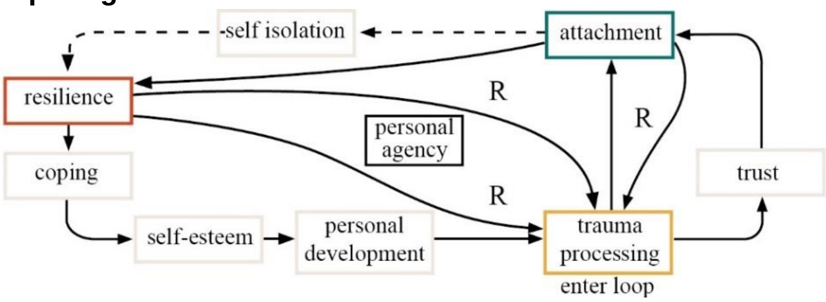

Figure 2. Core loop to facilitate personal agency for the child

The context of children with incarcerated parents is a complex issue that is hard to fathom, let alone tackle. Causal loop diagrams (CLD) [14] bring the dynamics of the issue into focus, which shows opportunities to influence change.
Figure 2 illustrates the core loop of the system that contains the levers that are targeted for intervention. The goal of the loop is to create personal agency within children with an incarcerated parent. Currently, these children have no sense of control, they feel powerless [1]. They lose confidence in themselves and their environment. The objective of the core loop is to facilitate the development of children’s autonomy and self-confidence. The core levers within the system are trauma, attachment, and resilience. These concepts form a reinforcing loop that leads to escalation [15]. In simpler terms, an intervention to process trauma will increase both the attachment and the resilience of the child. During the design process, this core loop will be the foundation. The final product-service system should empower children with incarcerated parents by reducing the child’s trauma, fostering attachment between child and parent, and building the child’s resilience.

3.2 Outcome map

The outcome map [16] (Fig. 3) synthetizes the analyses. It consists of a comprehensive, cohesive collective strategy and action plan to reduce and respond to the impact of parental incarceration on children [15]. The outcome map, simplified in this diagram, has five structural elements: the sustainable goal, the impacts realized through the achievement of the sustainable goal, the strategic impact, the strategic outcomes, and the associated actions. The map describes the long-term impact on the right and the short-term outcomes toward the left. The sustainable goal is the direct result of the activities and outcomes. The sustainable goal indirectly leads to the strategic impact through various impacts that arise by realizing the sustainable goal.

The strategic outcomes are based on the levers discovered in the core loop (Fig. 2) of the system. The outcome map is a systemic design tool using ideation techniques [15]. Hence, the map provides an understanding of the long-term goal and the short-term actions that must be implemented to achieve that long-term goal. The outcome map forms the transition from the analysis phase to the design phase. This tool allows the designer to start to concretize a complex problem. The activities hint toward design requirements for incorporating the service component of the product-service system (PSS), rendering the strategic impact viable and perceptible. The outcome map is the first step in designing the product-service system. However, the tool does not encourage enough creativity to determine what the product component should look like. The map is useful to transfer from the abstract long-term goals of a project, identified through the CLD, to the short-term actions necessary to reach the long-term goals. Consequently, another method or set of tools is essential to generate a fitting design process that defines the product component that delivers the service.

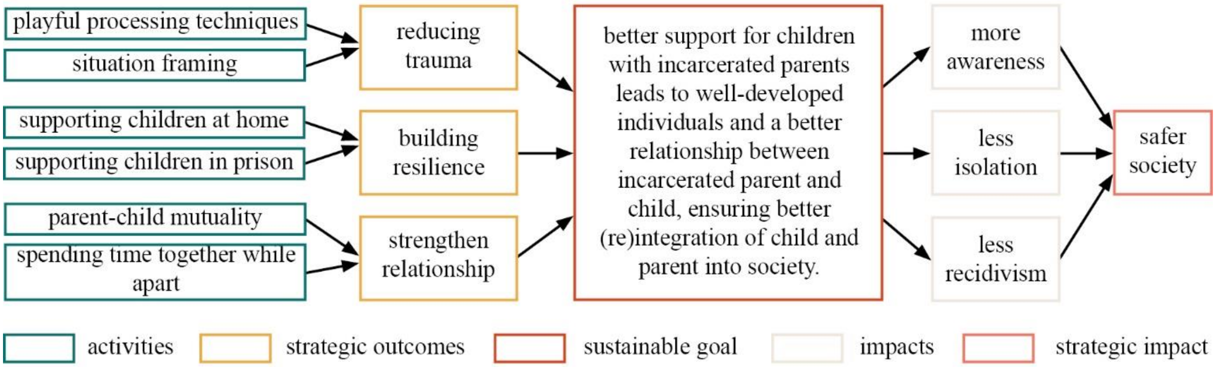

Figure 3. Simplified outcome map

4 PRODUCT-SERVICE SYSTEM DESIGN

Therefore, the product-service system design methodology is used to fulfil the need for creativity. PSS design has strong connections to both product design and service design. However, PSS design surpasses the individual disciplines and applies each other's tools and methodologies to tackle the complexity of today's issues. The aim is actual product-service integration [17]. The acknowledgment of the complex nature of society corresponds to the approach of systemic design. In this case, PSS design is a method to structure the design phase without losing sight of the initial leverage points. Thus, multiple tools are implemented to create solutions during the creative phase of the design project. The key tools that shaped the leverage points into a thorough PSS are the Lotus Blossom, the Niche discovery, Personas, and the user journey [18].

Figure 4. KIDO

The result of this design project is KiDO (Fig. 4), a product service system (PSS) for children with an incarcerated parent. Children of prisoners feel powerless because of parental incarceration. KiDO gives the power back to these children. The product-service system aims to improve the attachment between the child and the detained parent, reduce the child's trauma and strengthen the child's resilience. Children and their incarcerated parents are more often separated than together. KiDO captures these moments of loss by connecting children and detained parents up close and from a distance.

KiDO consists of one communication device for the child, one for the incarcerated parent, and six different types of cards. The *You, me, us* cards strengthen attachment, the cards are empty and ready to be filled with audio fragments from the incarcerated parent. Detained parents can store assignments, recipes, stories, treasure hunts, games, riddles, etc. on them, to which children can listen by inserting the card into the communication device. The yellow cards help to cope with trauma. The *This and that* card

explains a multitude of children's concerns about parental incarceration. While the *Ask a question* card enables children to ask questions in a barrier-free way. The pink and white cards build resilience, the *Do it* cards provide children with the right skill set to discover their potential and stimulate personal development. The *Reward* cards and the *Back-and-forth* card praise and encourage the children's personal growth. KiDO enriches the relationship between the child and their incarcerated parent. However, the aim is to encourage children to develop personal agency.
This design project in collaboration with CAW[1] focuses on children and their imprisoned parents within Hasselt prison, Belgium. While this ensures a defined case study, area for testing, and close collaboration between the designer, users, and the prison, it also means the product-service system is adapted to the operation of Hasselt prison and must comply with Belgian legislation and the policy of this specific prison [21]. However, Kido has certain flexible characteristics that render the PSS capable to adapt to different prison policies, such as the ability to record and exchange cards at any time, working with recordings to overcome language barriers, and aligning recorded tasks with the values, restrictions, and structures of diverse cultures and countries. Nevertheless, implementing KiDO in different prison policies may have unintended consequences, so further exploration of the specific prison cultures and policies is necessary for effective implementation and preparation for emerging behaviour.

5 DISCUSSIONS

The goal of the design project was to create a future-oriented solution for children with incarcerated parents that could be implemented in the current society. To realize this goal two approaches were combined, systemic design and PSS design. Systemic design maps out the complexity of the current situation and identifies possible leverage points for change [15]. While PSS design turns the leverage points into a tangible result ready for implementation [17]. CLD's determined the leverage points; trauma, attachment, and resilience. However, the challenge lies in translating them into concrete interventions. The outcome map was used to transition from the analysis to the design phase. Outcome mapping is a useful tool to explore the possibility space and to ideate new services. This technique offers a roadmap to connect the future strategic impact with activities achievable in the short term. Another asset of the outcome map is that it allows the designer to maintain an overview, it is a consistent reference throughout the design project. The map consists of both a strategic component, the long-term impact, and a design component, the current activities and direct outcomes. As a result, a continuous guideline is provided for designers who encounter complex problems.
Besides the advantages of implementing the outcome map, the tool lacks the incentive for product design. The further development of the product-service system needed another approach. The PSS toolkit [18] was applied to guide the designer through the design phase and materialize the product-service system. The transition from systemic sensemaking to PSS design happened through the outcome map. However, a design process has an idiosyncratic and free character, so this tailored transition may not always match the imminent challenge. Further exploration of methods on the transition or combination of systemic design and PSS design may help practitioners to devise implementable interventions without being paralyzed by the complexity of the issue.

6 CONCLUSIONS

Designers are increasingly faced with complex problems, yet they often flounder by the intangibility of this complexity. This paper has explored a way to embrace the complexity while still obtaining an implementable forward-looking solution as an outcome. By combining systemic sensemaking and PSS design, we created a product-service system solution that helps children with incarcerated parents cope with trauma, build resilience, and strengthen their relationship with their incarcerated parent. This paper suggests using the outcome map as a transition to move from abstract insights to concrete idea generation. However, further exploration of the transition between systemic design and PSS design is needed to understand its effect on the design process and the end result in order to adopt this combined approach to a wide range of complex issues.

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[1] The Centre for General Welfare Work (CAW) helps people with all their questions and problems related to welfare.

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RESPONSIBLE INNOVATION FOR GLOBAL CO-HABITATION

The 25th International Conference on Engineering and Product Design Education (E&PDE) with the theme 'Responsible Innovation for Global Co-Habitation' was held at the ELISAVA, Barcelona School of Design and Engineering, UVIC-UCC on the 7th and 8th of September 2023.

Design and Engineering have innovation at the core of their professional practice. Innovation might come from a technocentric drive, pushing technology to new limits without considering why or how that affects us as a society and a global community. The environmental crisis and the lack of improvement in areas such as pollution, biodiversity loss and climate change, demands that our efforts focus into new ways of co-habiting the spaces we share with each other, be it other cultures, other species, and the diverse eco-systems that support us. Thus, the E&PDE 2023 conference theme considered how might educators incorporate curriculum which will allows us to consider futures that are inclusive, fair, and pluralistic.

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