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TOWARDS THE CHEQUERED FLAG: A COLLABORATIVE CROSS LEVEL ENGINEERING APPRECIATION CHALLENGE FOR BSC PRODUCT DESIGN STUDENTS

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ABSTRACT
This paper concerns pedagogic research, which explores the process and student benefits of a collaborative 'design and build' engineering team activity. The need remains, post Finniston, for students to engage in engineering appreciation activities to fulfil the requirements of the professional accreditation body and the academic learning outcomes pertinent to both knowledge and skills, which often results in students producing small products or components, which require the use of a range of engineering processes. However, students often fail to recognise the relevance of such outcomes, fail to visualise the three dimensional outcome, fail to appreciate the connections between design, detail, manufacture, materials and management, in what is often perceived to be a fragmented engineering workshop activity, limited in scope and lacking in connectivity to the students' studio projects.
Therefore, a fresh approach was taken with the delivery of engineering design and manufacture appreciation amongst the 1st and 2nd year undergraduates. Combining students from both 1st and 2nd year into mixed level teams that had to collaborate on a much larger design and build activity, utilising the knowledge and processes taught throughout the year as part of the activity. The design and build project centred on the construction of an engineered and designed 'soap box' racer that was trialled in a local park at the end of the summer team, such a competitive goal helped to focus and drive the students.
Teams were constructed of an equal number of 1st and 2nd years whilst female team leaders where recruited four per level to lead the eight groups in 2013 with mixed group leaders in 2014. Students worked in their teams over the course of 6 weeks designing and producing ergonomic rigs, before commencing work on the 'soap box' racers, which required the students to design and produce a rigid chassis, fully enclosed bodywork and fully functional steering and braking systems.
This paper documents the findings from the project in relation to the success of the project, student collaboration, the knowledge and skills gleaned, and future recommendations and lessons to be learnt. These findings additionally consider the students own evaluations of the project and their individual role within it, through a reflective piece of writing. Additional findings relate to the enhancements of cross level collaboration, which extend beyond the project, including how the first years benefited from the second year students' hindsight in preparation for the year ahead.

Keywords: Design education, engineering appreciation, collaboration.

1 INTRODUCTION

The project work described within this paper takes part within the context of Engineering Appreciation (EA1 & EA2) within the BSc Product Design course at Nottingham Trent University. EA1 and EA2 are undertaken in the 1st and 2nd year of undergraduate study, which corresponds to National Qualification Levels (NQF) levels 4 & 5. The course is which is accredited by the Institute of Engineering Designers, therefore the aim of the associated teaching and learning in EA1&2 is to partially fulfil the Engineering Council accreditation requirements for Engineering Practice [1] to the Incorporated Engineer level. Such criteria are concerned with the practical application of engineering skills, through fulfilment of the following criteria:

- Knowledge of contexts in which engineering knowledge can be applied (eg operations and management, application and development of technology, etc).

- Understanding of and ability to use relevant materials, equipment, tools, processes, or products.
- Knowledge and understanding of workshop and laboratory practice.
- Ability to use and apply information from technical literature.
- Ability to use appropriate codes of practice and industry standards.
- Awareness of quality issues and their application to continuous improvement.
- Awareness of team roles and the ability to work as a member of an engineering team. [1]

Teaching within EA1&2 is less formal than the traditional lecture, seminar or tutorial formats that are typically found within Higher Education; instead teaching focuses more on technical instruction of core practical and physical skills in an engineering workshop setting. Students typically engage in these activities within small groups in one morning or afternoon every other week. EA1 sessions typically require students to produce components from engineering technical drawings, which require them to obtain and practice skills related to machining and fabrication, through the use of lathes & mills both CNC and manual, taps and dies and sheet fabrication using welding and other permanent or semi-permanent jointing methods. Whilst these activities endow the students with an understanding of engineering processes as intended by the original Finniston report [2] and lately the Engineering Council requirements, it lacks relation to the rest of the degree programme, due to the elementary nature of such skills training in the 1st year. Therefore a new end of year project was developed for 1st year student to encourage them to apply their EA1 learning and integrate this within a design and build project linked to their studio teaching in integrated projects. The intention of such an activity was to encourage them to enhance the creative problem solving skills within the more engineering skills based area and to develop teamwork skills in collaboration with 2nd year students.

2 METHODOLOGY

The soap box challenge activity was run at the end of the summer term in 2013 & 2014 with initial design work being undertaken by the students over the 2 weeks prior to the build, designing the mechanical systems and producing ergonomic rigs for their designated tutor driver. The build took place over the preceding 3-4 weeks and the race day was held in the first week of June.

The design of the specific challenge was to encourage 1st year students to integrate their EA1 skills within their design projects element and manufacture components that they have designed rather than manufacture from drawing given to them. The challenge also focused on soap boxes so that it encouraged 2nd year students to implement and integrate their learning from their Applied Technology studies, designing mechanical components and systems and applying knowledge on bearings and friction. The challenge was run with mixed teams of 1st and 2nd year BSc Product Design students, 7 teams consisting of 9 students each participated in 2013 and 8 teams of 8 students participated in 2014. Students were permitted to select their own groups; however in 2013 female team leaders were picked 4 from each year group. This decision was made as there were far fewer female students in each year group with a ratio of 1:5, this lower number made the selection of team leaders far easier. Female team leaders were also chosen to promote female engagement in the challenge and ensure that it didn't become an activity dominated by a few competitive male students. However, as the findings detail having 1st year students as team leaders introduced problems and so for the 2014 challenge team leaders were elected solely based on academic merit and personal choice.

2.1 Challenge rules and constraints

The challenge was subject to a number of specific rules and constraints that students were briefed upon before they started. These covered numerous requirements and included the position of the driver who had to be seated in a feet first position; head first and lying down positions were banned. The steering was required to be a solid solution; rope pull steering for example was banned. The soapbox also had to have driver operated braking on a least one of the wheels, the driver also required a seat and to be enclosed and protected from moving parts such as the wheels or ground. A number of other specific restrictions were put in place for the 2013 challenge, including the requirement that the soap box had four wheels, which had to be of a specific size and were supplied to the teams. The soapbox also needed to be able to be flat packed for ease of getting to and from the testing site and for dismantling at the end of the competition. The soap box also had to be styled in the form of a 1930's racer. These final restrictions were removed after a review for the 2014 challenge.

2.2 Analysis

The findings of this paper were informed by the students' reflections upon the activity both in 2013 and 2014 as well as staff reflections and observations. The students were asked following the challenge to write a short reflective piece of writing limited to 2 sides of A4 on the success of the activity, responding to the following 6 questions:

- How did you find the brief, technical and practical requirements?
- How did you feel you worked as a team?
- How did the individual members of your team work and how was the team led or how well did you feel you led the team if you were the leader?
- How did you find the experience of working with 1st/2nd year students? Was this beneficial to you and did you learn from the experience.
- Did you feel that you applied your knowledge of engineering principles and practices?
- What did you feel that you learnt? This could be knowledge, management techniques, practical skills or social interaction.

The findings from these reflections informed the development of the challenge from 2013 to 2014 as well as the findings presented in this paper.

3 FINDINGS

The individual student reflections were considered by the lead author and the students comments and reflections were grouped accordingly to common themes that were derived from the questions posed to the students and the students own thoughts.

3.1 Use of EA principles

The use and practice of EA skills within the project varied between the 2013 and 2014 challenges. Due to the flat pack rules imposed on the build of the soap boxes in 2013 most of the construction required the use of non-permanent methods, with students largely using Dexion secured with nuts and bolts for the chassis see Figure 1. However, welding techniques were employed on aspects of the steering, and turning and milling were employed by the majority of the teams in order to machine the steering linkages as well as braking components in some cases. It was found that the relaxation of the rules in the 2014 challenge was much more suited to a wider use of EA techniques. The greater freedom in the rules, permitted greater creativity in the solutions and components manufactured, with more students demonstrating a wider range of fabrication methods and much greater uptake of welding in comparison to the previous year see Figure 4.

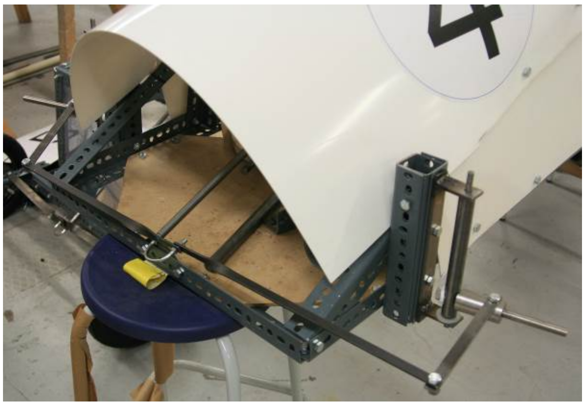

Figure 1. Soap box construction in 2013

3.2 Student Engagement

The exercise was found to be particularly engaging; however students struggled with effective time management and the freedom given in the 3-4 weeks of the build. As a result 2 soap boxes failed to run in both 2013 and 2014 challenges due to being incomplete or being deemed unsafe following a rushed finish. However those that did compete in 2014 were more reliable and successful demonstrating progression. Of the 6 soap boxes that were allowed to run in 2013 only 3 completed the route, whilst all 7 of those that were allowed to compete finished the route in 2014.

The activity fostered a very competitive spirit amongst the students, with all wishing to run their soap box and very high attendance on the final race day across both years despite it being the penultimate day of term. The activity also encouraged some students who previously lacked academic engagement to engage highly due to the practical and competitive nature and this increased engagement filtered through to enhanced attendance beyond the challenge. However some students who usually engaged well on other more academic aspects of the course took the challenge less seriously as it was seen as a fun rather than academic activity and this typically affected 2nd year students more than 1st year students.

The activity helped to build relationships between the two cohorts with 2nd year students sharing their experiences of looking for placement and dealing with the increased workload in 2nd year with their 1st year counterparts, whilst the 1st years' enthusiasm and in some respects fresh outlook and approach was beneficial to the 2nd year students also.

The choice of female-only team leaders in 2013 wasn't ideal as it was found that the 1st year students lacked the experience and confidence to lead the teams and even began to resent being the leader in two cases. In these instances the leadership was then assumed by a 2nd year male student within the team. Therefore in 2014 the criteria for team leaders was that it should only be 2nd year students who wished to lead a team for which there was a more representative gender distribution with one female team leader and 7 male team leaders, better reflecting the gender makeup within the course.

3.3 Innovation and Creativity

It was found that although the 'flat pack' approach to the racer's construction for the 2013 challenge was a practical one, it was very unpopular with the students who saw it as a restriction too far and felt that it negatively affected their teams and soap box performance. In addition to this, whilst a number of the students really got into the spirit of the 1930's racer style, a number also felt that the aesthetic styling requirements were constraining and detracted from time that would have been better spent on perfecting the mechanical aspects of the soap boxes.

Figure 2. Chassis twist on a 1930's style soap box

In light of this the challenge brief had fewer constraints in 2014, with no guidance on construction or styling, instead the students were asked to consider the reuse of materials within the construction of the racer and a major change also permitted the development of 3-wheeled soap boxes, which were previously banned in 2014. However, the main considerations of braking on at least one wheel, fixed solid steering and a feet first driving position were maintained in both years/ In addition for soap boxes to compete both the steering and brakes were required to be functional for safety purposes.

The reduction in the constraints in 2014 meant that there was far greater creativity and variety amongst the eight entries see Figure 2, which was surprising considering that the 2nd year students had already engaged in the exercise the year before and therefore could have been expected to revert to what they knew.

Figure 3. Variation in the 2014 soap boxes

A delay in the order of materials in the initial stages of the 2014 challenge also increased the creativity and innovation demonstrated by the students, using what they could find resulted in a significant increase in the uptake of upcycled elements, with a number of teams cannibalising abandoned bicycles, utilising frames, wheels and braking components within their creations see Figure 3. 3 out of the 8 teams chose to incorporate larger bicycle wheels within their soap boxes on either the front or rear axle as opposed to the smaller wheels that were supplied. This completely changed the dynamic of the competition and enabled the students to be more creative as well as requiring them to overcome new challenges that came with the larger thinner profile wheels such as a changed centre of gravity, the need to shroud the drivers, addressing the different bearing tolerances and excessive wheel camber and in one instance material fatigue and failure mid run.

Figure 4. Bike derived soap boxes 2014

4 FURTHER WORK

The soap box racer activity has been a useful and fun activity for the students and will be continued albeit only with 1st year students due to increases in cohort sizes. However alongside this activity further action has been taken to increase the engagement of students across within the engineering appreciation workshops. In the 2014-15 academic year more focused activities were implemented within the EA1 curriculum and these have been formally assessed for the first time by the technical staff. The activities require every student to make full use of the variety of machining and fabricating facilities and the decision to introduce formal assessment to be undertaken by the technical rather than academic staff was taken to increase the perceived importance and relevance of the workshops, granting greater autonomy to the technical staff. The result of these changes has been very positive encouraging 100% attendance from students most weeks in an area of the curriculum that previously suffered from very poor attendance.

Furthermore the integrated approach that has been fostered between the engineering appreciation requirements and other aspects of the curriculum with the soapbox challenge will be explored further in coming years. For instance there is an intention to introduce an injection moulding project in future EA2 classes that would combine the study undertaken in integrated projects, materials and manufacturing and utilise skills obtained through engineering appreciation to produce simple injection mould tools.

5 REFLECTIONS

Whilst the soapbox challenge was successful in many respects, lessons have been learnt throughout the past two years of running the challenge. Predominately these include the failure of the academic staff involved to socially engineer the student groups to encourage female engagement and leadership. Across both 2013 and 2014 engagement from the female members of the course appeared consistent therefore the initial concerns regarding the involvement of the female members of the course were invalid. Furthermore whilst tightly constrained briefs can be very beneficial with a studio environment mimicking the reality of industry it was counterproductive in respect to a competitive design and build activity. The constraints within the 2013 challenge overwhelmed the students to the point that the variation and innovation in the soap boxes suffered, in much the same way as some critics consider modern motorsport to be afflicted by a prevalence of rules. The relaxation of the rules in 2014 made the exercise far more enjoyable to the students and improved the outputs of most teams.

With increasing cohort sizes on design and engineering courses in undergraduate study it becomes more difficult to be able to run and manage such challenges, however the opportunity for students to ‘get their hands dirty’ in design engineering has never been greater [3] and therefore such a practical focus must be maintained. The benefit of activities such as this soapbox challenge are not merely limited to an application of knowledge; the experience has shown that students really enjoy the community aspect of such activities as well as the opportunities and benefits arising from having to operate outside of their comfort zone, where they can’t hide behind abilities in CAD or sketchwork.

Figure 5. Final run 2013

Figure 6. Winning team 2014

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