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PRODUCT DEVELOPMENT COURSES IN E-LEARNING ENVIRONMENT

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ABSTRACT
A new Product Development course has been established within the introduction of Bologna framework scheme at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb in year 2002. E-learning support tools have been introduced with the new course. Expectations from new technology are always high, but evaluation of efforts, resources and prerequisites needed to utilize technology and maintain the benefits through generations of students are often underestimated.
Proposed paper will illustrate practical experience gathered so far in an attempt to systemize and organise lessons learned. Particular attention is drawn to the learning outcomes which could suit this multidisciplinary and multicultural academic enterprise. Learned lessons will be applied to improve future courses.

Keywords: Product development course, e-learning, engineering design education

1 INTRODUCTION

Faculty of Mechanical Engineering and Naval Architecture has educated about 90% of master students in mechanical engineering and naval architecture in Croatia. Since the enrolment of the first generation of students back in 1919 faculty trained engineers to support the technological and economic development of society. It provides students with training in a wide range of engineering fields among whom the two: engineering design and energy and process engineering gain most interest of prospective students.

Following the changes in engineering theory and practice the faculty constantly updated existing courses to keep alongside with the latest developments in technology and, where necessary, introduced new courses to meet the changes.

A new Product Development education stream has been introduced within the implementation of Bologna framework scheme fostered at the national level. The aim was to implement more reflective teaching and learning, moving the focus from a procedural approach to reflection and conversation for gaining understanding and perception. The resultant courses were created aiming for a comprehensive lifecycle perspective of the disciplinary knowledge as well as development of student competencies such as responsibility, creative thinking and group dialogue. Assessment was pursued by a combination of oral presentation and written and project based examination. E-learning support tools have been introduced with the new group of courses in order to enhance availability of courses' material and communication with teaching staff.

Students experienced e-learning as a support tool and add on source to regular lectures and exercise hours. Adoption was almost instant; there were no reluctance to, or difficulties in accessing or usage of, new technology.

The first general conclusion to be drawn was that this type of learning was perceived as very different for the students compared to earlier courses enhancing students' interest for product development, increasing understanding for noncore-engineering aspects of product development (marketing analysis, industrial design) motivate self learning and increase students' communication and presentation capabilities.

2 PRODUCT DEVELOPMENT STREAM OF COURSES DEVELOPMENT

The new product development education stream was built based on the consideration about requirements for the modern engineers that are well documented in literature [1-2,10] and are results of the discussions with Croatian and Slovenian industry. Especial important insights for new produce development education stream were results of the several workshops on design education held during the series of the international design conferences DESIGN (www.designconference.org) from 2000 – 2006 in Cavtat Croatia.

Engagement in all phases of product lifecycle, complexity and multidisciplinary approach, teamwork, creativity and innovation are recognised as the main descriptors of the working environment for the modern engineers.

Therefore instead of the existing education o the engineering methods and tools, the focus of the new education approach has been moved toward the whole product development process including engineering, management and ethical issues (Figure 1).

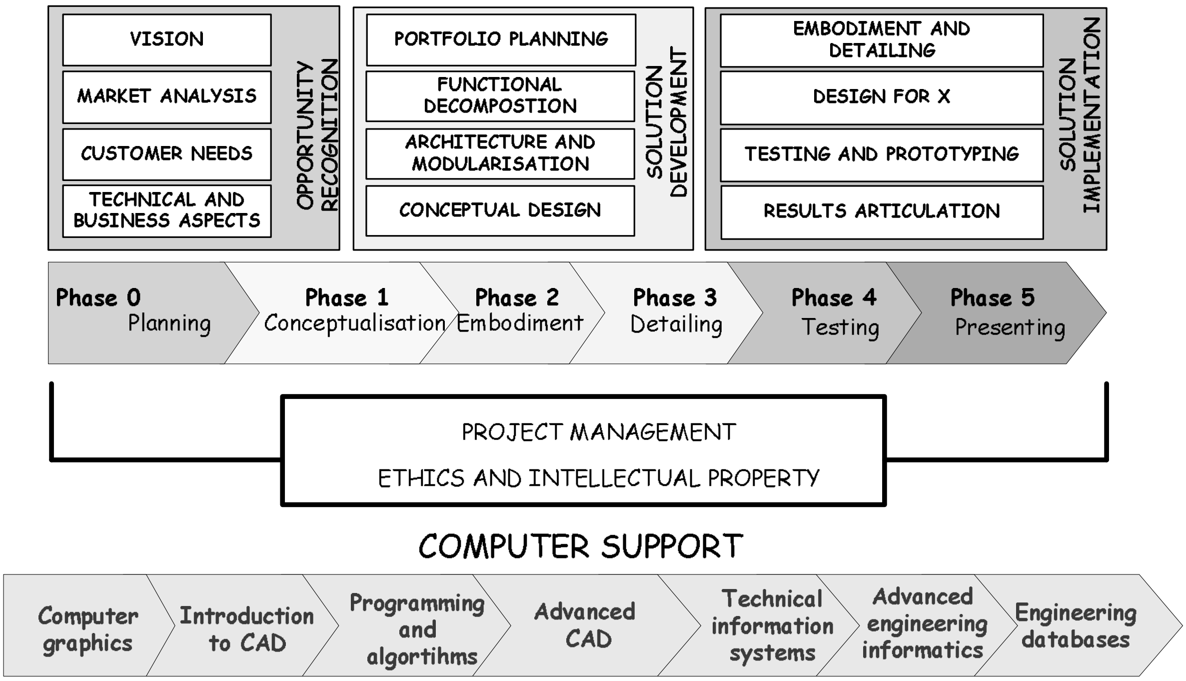

Figure 1. Educational model of Product Development Process accordingly to [3-7]

In parallel to the product development methods stream, the courses related to the computer aided support of the product development methods have been also introduced and developed.

The new product development group of courses have been further developed accordingly to the upper part of the Figure 1 into 3 parts:

- **Introduction to Product Development.** The goal of the course is to give an introduction to multidisciplinary aspects of product development and innovation. During this course students should familiarize themselves with basic terminology and methodology that could be used in product development projects. Practical problems should be considered in cooperation with companies in order to simulate real product development situations.
- **Engineering Design and Product Life Issues.** The course aims at creating an understanding of the activities of innovation and technical innovations. It helps the students to comprehend innovation techniques and be able to create innovative technical solutions by their use. The use of the techniques is focused on product life oriented design and product life systems by introducing different design for x methods (environment, ergonomics, manufacturing, safety, services, etc.).
- **Integrated Product Development.** The goal of the course is to learn principles of the project integration, experimentation and virtual development in order to consider product development in the light of the business strategy of the company. The central part of the course is product development project where students will develop the new and innovative product for different areas (health, environment, agriculture, etc.) and deliver full technical description for it in order to be ready for prototyping.

2.1 Learning outcomes

For the each course the expected learning outcomes have been defined as a starting point for course structuring and development. The outcomes for each course are presented in Table 1.

Table 1. Learning outcomes of course stream

Introduction to Product Development	Engineering Design and Product Life Issues	Integrated Product Development
• To be able to understand the technical and business aspects of the product development process. • To be skilled in implementation of gathering data from customers and establish technical specification • To be skilled in creating product functional decomposition • To be able to participate in engineering problem solving • To be able to understand the principles behind product modularisation • To be able to understand ethical and intellectual property issues in product development	• To be skilled in practice of defining and solving engineering problems. • To be able to understand human behaviour in product lifecycle. • To be able to understand manufacturing and assembling issues for product development. • To be able to understand environmental effects in the product life cycle. • To be able to understand ergonomic aspects in product lifecycle. • To be able to understand safety issues in product lifecycle. • To be skilled in implementation of product-service systems.	• To be skilled in market analysis and recognition the opportunity for new product development. • To be skilled in patent search and innovative problem solving. • To be skilled in modelling the product in conceptual phases of the product development using standard languages and tools. • To be skilled in embodiment and detailed design of the new product. • To be able to plan simulation and experimentation of the solution in each phase. • To be able to articulate and present results of the development project.

Final structure of the course stream and integration of the courses into standard ME curriculum is shown in Table 2.

The template of the same structure has been created in e-learning environment (Moodle) and reused for each course providing the unique learning environment for the whole stream.

The main elements of the e-learning support template are:

1. Execution plan of the course;
2. Teachers and students forum;
3. Course wiki with description of the all activities, assessment method and student evaluation procedures;
4. Templates for the student assignments;
5. Lecture material including external references on web sites, articles, and book chapters;
6. Self assessment quiz for each lecture;
7. Additional discussion forums for advanced topics;
8. Examples of the reports and projects;
9. Course evaluation form.

Above is the standard structure that was realised in time as courses have progressed. The wiki was not developed for the first generation. Developed as reaction to overwhelming email discussions, wiki proved to be an effective tool to reduce discussions regarding frequent questions and an essential part of the course materials.

Table 2.

Course:	**Introduction to Product Development**	**Engineering Design and Product Life Issues**	**Integrated Product Development**
Semester	5th (undergraduate)	6th (undergraduate)	1st (graduate)
Duration (hours)	45	60	75
ECTS	3	4	7
Expected number of students	~100	~40	~20
Execution model	Lectures including 2 written partial exams; 3 exercise tasks (requirements analysis, functional decomposition, concept generation and evaluation) 1 seminar (QFD)	Lectures including 2 written partial exams 3 exercise tasks (conceptualisation based on the new technological principle, embodiment and detailing, design for disassembly and environment) Up to 5 forum discussions on advanced topics	Lectures 1 team development project (3 milestones for report delivery – analysis of the situation and specification definition, concepts, detailed product documentation)
Lectures structure	01 Introduction 02 Product development process 03 Technical and business aspects 04 Product development planning 05 Identifying customer needs 06 Establishing product function 07 Creativity and innovation 08 Concept generation 09 Concept selection and testing 10 Ethical issues and intellectual property	01 Introduction 02 Defining and solving engineering problems 03 Product life issues 04 Product architecture and modularity 05 Embodiment and detailing 06 DfX: Design for Manufacture and Assembly 07 DfX: Design for Environment 08 DfX: Design for Safety and Ergonomics 09 Product Service Systems 10 Design methodology - theory and practice	01 Introduction 02 Product development models and strategies 03 Computer Aided Innovation 04 System Modelling Language SysML 05 DfX: Design for Failure and Robustness 06 Building and testing prototypes 07 Complexity management in product development 08 Concurrent Engineering 09 Virtual product development 10 Future of product development

The learning process in the course stream is designed to enable students gradual learning by experience, based on problem based tasks in the beginning up to project based learning at the end. The emphasis in the first course are given to social and ethical issues and students' "soft skills" : data gathering, information search, communication and presentation. Examples of the final students' assignments during **Integrated product development** course are presented on Figure 2.

3 DISCUSSION

E-learning tools have significantly raised the amount of communication between students as well as between students and teachers. Networking and communication between students overcome team boundaries. Open discussion forum enabled students from different teams to recognise problem patterns and discuss about with colleagues that have had assignments even in quite different product domains. In a way such discussions may be sought as by situation provoked analogue thinking.

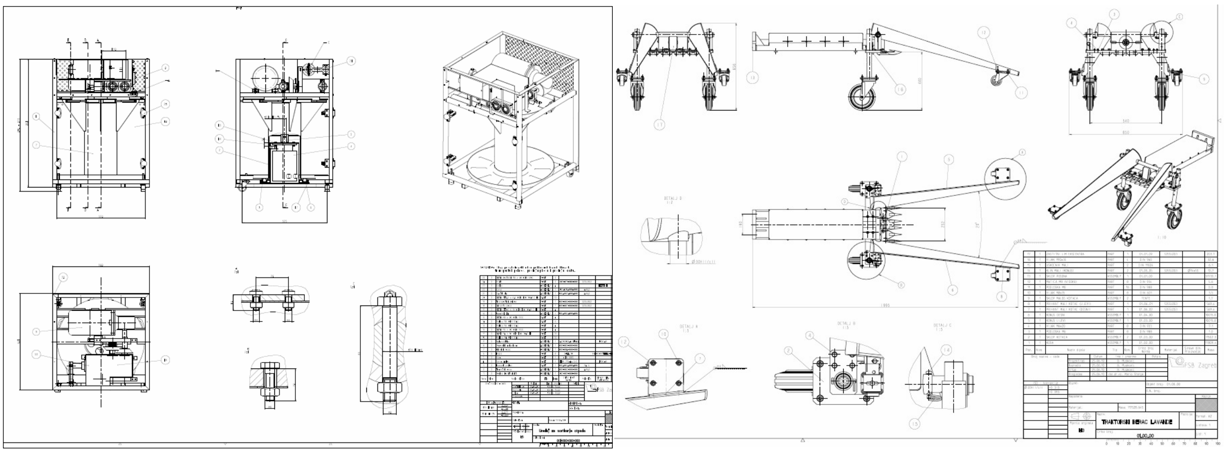

Figure 2: Medical garbage selecting and packing device (left), Lavender harvester as tractor attachment

Forum and email discussion provoke a stream of “ad hoc” questions or sets of questions (the later indicates reasoning process behind the sets) that are seeking for specific answers, or set of answers expecting specific answers. In most cases there is no single definite answer, rather there exists multiple possible answers that may be known but also some not known without additional questions. Such situations require acting in uncertainty situation.

The nature of discussions indicates draw back in students’ reasoning thread comparing to team face to face meetings. Particularly in the conceptual phase when continuity of raising questions and advantages and disadvantages argumentation of candidate solutions is fragmented.

For the teachers such discussion has been unexpectedly more time consuming than face to face with students in both forms individual or by teams.

Although not exactly measured teachers experienced improvements of students capabilities through course stream. Individual difficulties in the first course in the row have been recognised in the following aspects:

- managing ambiguity in problem statement,
- evaluation criteria for the intermediate project outcomes,
- lack of system thinking skills,
- taking decision especially when multiple candidate solutions are evident,
- communicating ideas and thinking at different levels of abstraction,
- synchronising the team structure and balance the team members task load,
- justifying the team members efforts.

3.1 Students reflections

Course: Introduction to product development

- If possible include more of students’ assignment proposals
- Skip partial exams – not needed. Everything else OK.
- Too many emails from forum discussion- overloading inbox.
- Less home work please.
- Requesting to much home work. Part of the assignments could be delth during excersise hours. Students’ presentations – very good and useful.
- Previous year students’ assignments could be used on exercises as case studies and “not-to-do” examples.
- Far too many assignments! Home works interesting and stimulating!
- Last assignment far too demanding.
- Home assignments and seminars are time consuming.
- More different solutions for same case problem. Could easy understanding of functional structure.
- More practical engineering experience is needed for such tasks.
- Team distribution is bad. Conceptual design in teams cannot be justified. Some students do all the work.

- Same grades for the whole team are not fair.

Course: Engineering Design and Product Life Issues

- Partial exam test is not good.
- Excellent course, well prepared good course materials.
- External links to sources are the best part. Enable wide picture.
- More real case studies could easy understanding.
- Far too many information per lecture.

4 CONCLUSION

Although students and teachers have been satisfied with the outcomes the main problems in students' education have not changed comparing to situation before e-learning. The changes are notable in tracking and documentation capabilities the course are very similar to those that arise in real case situations and are not tackled by e-learning technology. Somehow those problems may be considered as the core of engineering education. In our experience those are:

- **Defining the Problem** – the design oriented course involves practical problems to be solved. In order to design, analyse and construct the problem must be clearly defined which in education that is "a simulation" of real case could be ambiguous.
- **Selecting right tools for the problem** – getting CAD tools under fingers is the students' first impulsive choice, basic analysis and thinking is missing.
- **Developing the right concept** – this is a consequence of several factors. Weak sketching skills that lead to CAD modelling without proper analysis or evaluation of candidate solutions is the one, while another arises from the first item: the weak problem definition.
- **Developing clear functional structure –** differentiation between functions (software) and components (hardware) is a consequence of misunderstanding between modelling tools: the analytical (often math) language and engineering language.
- **Keeping it simple** – in attempt to perform better simple solutions are abandoned as "too simple to be good".
- **Tackling environmental issues and safety** – as beeing (most regulary) not measurable those are not included in List of requirements, and consequently are not considered.
- **Detailed design -** in the embodiment phase where particular attention must be drawn to details, part selection or design, material selection and compatibility the problem remains the same regardless solutions are generated by hand or by "computer" .

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