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A STUDENT'S INTERDISCIPLINARY PRODUCT DEVELOPMENT PROJECT IN ENGINEERING DESIGN EDUCATION

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ABSTRACT
Within the bachelor education for different engineering programs a basic interdisciplinary product development project is the fundamental part of a three-level project-based education plan at Lucerne University of Applied Sciences and Arts. The project teams consist of up to seven students from mechanical-, electrical-, business-engineering and computer science. All teams have the same inputs and tasks varying from year to year – usually with mechatronics background. During two semesters the teams learn in a practical, hands-on way the different aspects in today's product development, such as:
(customer) need finding – define – design/test – supply – produce – solution (product).
The first semester is focusing on the need finding and definition phase, whereas the second semester is focusing on design loops including prototyping, test and supply. Students have to set-up all requirements and specifications for their individual solution, do the proof of concept and build up a functional prototype with a limited pre-defined budget. Another important aspect of this kind of engineering education is social networking and social aspects within the project framework. For validation a one-day competition is the final event of the engineering learning project.
The basic teaching concept is presented. The advantages and limitations are discussed and explained with practical experiences from the last years and feedback from the participants, lecturers and the alumni network.

Keywords: Design education, interdisciplinary engineering projects, active learning

1 INTRODUCTION

Lucerne University of Applied Sciences and Arts, is one of seven publicly funded Universities of Applied Sciences in Switzerland. With more than 1'700 students and 200 faculty members, the School of Engineering and Architecture is a part of Lucerne University of Applied Sciences and offers the following technical bachelor's degree programs, see [1]:

- Architecture
- Interior Design
- Civil Engineering
- Building Technology
- Computer Science
- Electrical Engineering
- Mechanical Engineering
- Business Engineering

The typical incoming students have finished apprenticeship and have obtained a vocational baccalaureate, which enables them to study at a University of Applied Sciences (tertiary education level). The degree programs have a modular type set-up, thus enabling students to put together a program that reflects both personal needs and interests. For example, students can choose between *full-time* and *part-time* studies (e.g. for employed students).

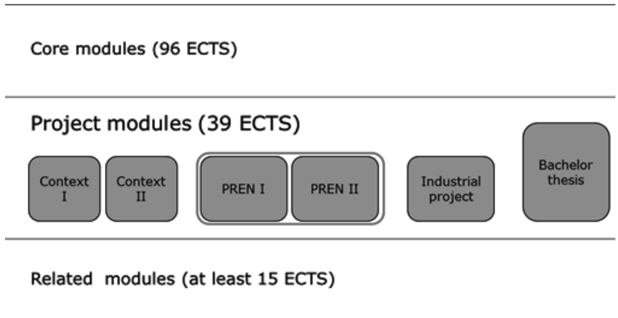

Figure 1. Project modules, curriculum [2]

From the very start, students are involved in research and development projects with partner companies. This is emphasized by a unique project-based curriculum (39 of 180 ECTS are scheduled for project modules), see Figure 1. In addition interdisciplinary project teams are composed involving the departments of mechanical and electrical engineering, computer science, and business engineering, ref. [2].

2 PROJECT-BASED EDUCATION

With regard to problem-based learning the following propositions are found [7]: compared to a lecture-based teaching the students

- generate explanations themselves
- find superior explanations and understanding
- remember the concepts learned better
- integrate new concepts with existing knowledge
- analyze problems and communicate in a team
- the coaches can interact and help specifically

The team-work is coached by experienced professional lecturers, who promote innovation through various methods. An on-site FabLab can be accessed anytime to make new ideas tangible.

Extensive engineering laboratories and workshops in the areas of materials, electricity, thermodynamics and fluid dynamics offer opportunities to conduct hands-on experiments, see Figure 2. The use of the equipment and the analysis of results are performed in small groups and coached by on-site experts.

Figure 2. Interdisciplinary project team-work

As all other offered modules, the mentioned project modules (Figure 1) are arranged in a three levels set-up within the degree programs: *1st level - foundation* (Context, team project, focused on project skills and technical documentation), *2nd level - intermediate* (PREN, team project, focused on product development and engineering skills), *3rd level - advanced* (industrial project and bachelor thesis, individual project with partner companies). The project modules are *compulsory modules* and the registration is checked by strict admittance rules (i.e. participated and passed supplementary core modules).

3 PRODUCT DEVELOPMENT PROJECT

3.1 Set-up

With regard to engineering design education, the heart of the three level project modules is the *Product Development Project* (PREN) module. Engineering design methodology here is taught in a problem-based learning approach, giving an hands-on understanding of the product development process for the most relevant phases from initial needs to final solution, see Figure 3. In addition the students have to work in teams, co-operate with the different technical domains (mechanical, electrical engineering, computer science and business engineering) and tackle very practical project problems, like organizing, planning time schedules and social interaction (e.g. notice conflicts within the team).

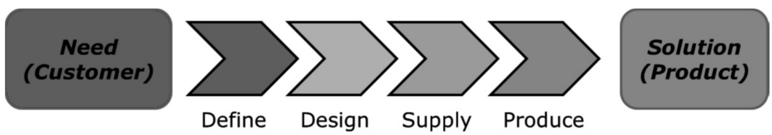

Figure 3. Product development process

The design process is defined in a systems engineering context [3]. The teams usually start with given system requirements of a mechatronic system. From these, the domain specific design specifications (mechanical, electrical and software-related) are derived for the components. Component tests are defined, component prototypes built and tested and integrated to the final system for system validation – according to the v-model approach.

In the actual form, all teams have to solve the same task (normally a mechatronic system), the team solutions are discussed within the teams but not shared between different teams, a competitive set-up is used and resources and budget are limited. The teams get all necessary information in regular input sessions by the lecturers. A weekly coaching is offered, and preliminary results are presented on a regular basis. The coaching is provided by team-specific lecturers and not by technical assistants or students. The coaches accompany their teams during the full module duration of two consecutive semesters.

3.2 Execution

The general procedure during the first part of the module can be described as follows:

- Design brief, requirements ***(what is the task)***
- Project planning and basics of project control [4]
- Functional decomposition
- Concept studies ***(how to solve)***
- (Rapid) prototyping and functional testing of basic concepts, optimization (***fail early***)
- Description of the final system concept

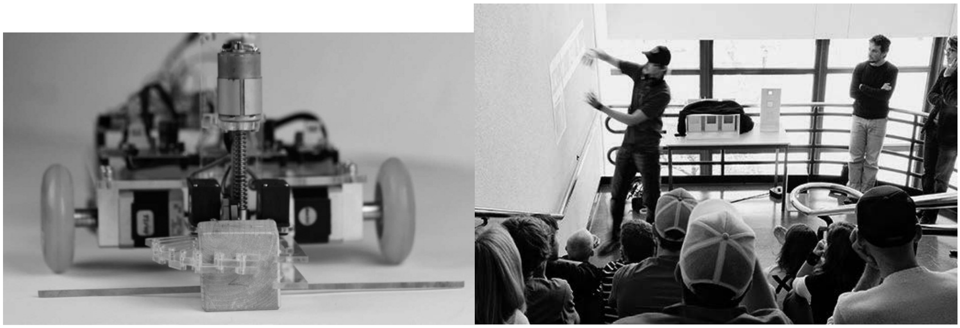

Figure 4. Example of final concept of mechatronic system, public presentation

The students are encouraged to use the workshop infrastructure of the school to built-up and test their functional prototypes for proof of concepts. Most of the measurement equipment of the labs and the on-site FabLab [5] are available and open for supporting project studies.
The realization of the final system concept, see Figure 4, is subject of the second part of the product development project:

- Project planning for tasks, parts, system integration, costs
- Coordinating and merging domain specific results
- Derive domain specific details (drawings, electronic schemes/layouts, software architecture)
- Approve and release ***(admit one's responsibility)***
- Supply of parts and/or manufacturing (***make it real and tangible***)
- Assembly and testing
- Final system tests, documentation and presentation, see Figure 4
- Competition event ***(making results public)***

3.3 End of project / result

The progress of the projects and the motivation and engagement of the project teams is strongly affected by the competitive character of the execution and the final competition at the end of the module. I.e. the team's solution is public and is on trial, see video [6].
Beside the final event the teams have to deliver their complete documentation and give a presentation on their results. The presentation is also public and documentation is double checked by external reviewers.

4 LESSONS LEARNT

The proposed project-based education represents a paradigm shift from traditional lecture-based engineering teaching and learning philosophy. The experiences and feedbacks for many executions are throughout positive both for lecturers and students (school's evaluation system, EVAL). Continuous improvement especially regarding the task descriptions results in a highly accepted module, accounting for different competencies needed for today's and future practical engineering situations, such as:

- Bring in technical and engineering know-how to other
- Personal and social experiences
- Organizational and project skills

Figure 5. Verification and evaluation in team reviews

Working in interdisciplinary teams, students identify what they already know (current status: 3rd and 4th semester), what they need to know, and how and where to access new information that may lead to resolution of the problem. Learning in the team and by the team (Figure 5) students also gather hands-on engineering skills in the labs and engineering workshops. During execution at the beginning the key is to understand *what* and *how* and to accept (early) *fails*.

The constructs for teaching in a project-based environment are very different from traditional classroom/lecture teaching. Table 1 gives a summary of actual resources needed, where school's infrastructure (rooms and workshops) is the limiting factor.

Table 1. Number of teams and involved coaches

# team members	# teams / coach	# teams total	# students / year
6-8	2	25-35	150-280

As for all teaching concepts an adequate module assessment scheme is essential for good acceptance. The proposed product development project is using a combined assessment of the teams by their team-specific lecturer, evaluation teams and a group of external experts with a defined milestone system, see Figure 6. Binding commitments both for the lecturers and for the students support engagement and motivation during the two semesters. The final event with competition, i.e. making team results public is strongly enforcing one's responsibility and is in addition a kind of gratification *making it real* and *tangible*.

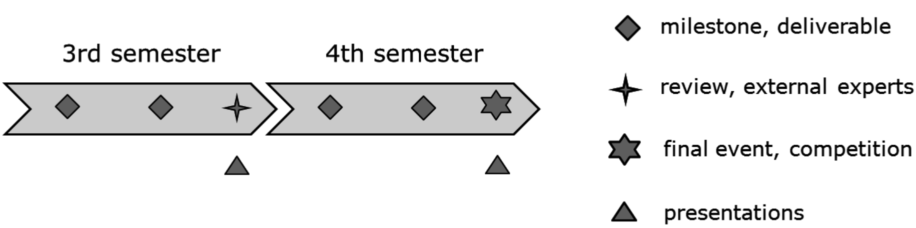

Figure 6. Project module assessment scheme

After 7 executions and about 1'500 students in total having participated in the project modules, the active learning is well established at Lucerne University of Applied Sciences and Art. A more flexible knowledge, effective problem solving and collaboration skills and intrinsic motivation is imparted. Especially the team interaction is essential for successful results and students achievements, confirmed by recent education research reports [7]: e.g. the increased verbalizations of concepts during the reporting phase led to higher achievement, and collaborative learning may be more important than individual study.

For the near future some adjustments to the module set-up is planned to become more flexible to changing number of students in the different programs participating, or regarding new created degree programs and also for the international module programme (in English).

5 CONCLUSIONS

A project-based engineering education concept is presented and discussed. The main reasons for using such an approach are:

- To experience the usefulness of one's own actions in a team as main motivation to work in a new, innovative and challenging future environment
- The strong individual intrinsic motivation of the involved team members is very effective and a sustainable experience
- The individual coaching creates a working atmosphere as found in a professional environment
- This makes the project-based learning more authentic
- Interestingly, the majority of students achieved competencies which are significantly above the goals defined by the lecturers (interview feedbacks of students, lecturers and alumni network)

The effectiveness is shown by the level and the quality of the bachelor thesis (final, individual work). In addition the positive results of employer surveys are clear indicators that the hands-on, project-based learning is well suited and is an adequate concept imparting professional and personal skills to the engineering students.

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