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PROJECT-BASED LEARNING IN UNDER-GRADUATE COURSES AT THE UNIVERSITY OF STUTTGART – EXPERIENCES AND CHALLENGES

Robert WATTY and Hansgeorg BINZ

Institute for Engineering Design and Industrial Design, Universität Stuttgart, Germany

ABSTRACT

Industry's demand for ready-for-practice graduates challenges the education at university. It implies that students must have deep knowledge of "the fundamentals" of professional engineering and the ability to apply it in practice. Therefore, curricula and accreditation criteria for successful study courses increasingly include the teaching of communicational, methodical or personal skills. Project-based learning is one of the models that are nowadays favoured in pedagogics for this purpose. The use of design projects is a promising way to acquire these key competences in engineering courses that was successfully introduced for undergraduate students at the Institute for Engineering Design and Industrial Design in 2003 and repeated in 2005 and 2007.

This paper describes theoretical background, planning and implementation of the realised design projects, their evaluation and consequences drawn as well as a modified didactical approach for future projects.

Keywords: Project Learning, Design Education, Design Projects

1 INTRODUCTION

Professional engineers do not only require technical knowledge but also the ability to apply it successfully to design problems in the "real world". Thus both requirements of industry as customer and upcoming demands of accreditors for study courses in the Bologna process challenge the education of design engineers at university to "prepare graduates for the practice of engineering at a professional level" [1], [2]. The necessarily required soft skills can be acquired by solving realistic design problems in order to cope with for example holistic technical tasks as well as work organisation or conflicts in design teams. Project-based learning is a model to implement practice-oriented education in undergraduate courses [3].

In 2003, the Institute for Engineering Design and Industrial Design (IKTD) at the University of Stuttgart for the first time decided to confront teams of undergraduate students in their fourth semester with a technical project to extend the learning target from purely technical aspects of drive engineering to a broader view on design engineering tasks.

2 DIDACTIC APPROACH

Employers ratings of the importance of EC2000 accreditation criteria [4] take a firm stand concerning requirements to new staff.

Technical knowledge, its appliance and the use of modern engineering tools are still highly relevant and essential competencies for engineers. Nowadays they must be supplemented by personal skills, e.g. communication or teamwork ability, ethical responsibilities and the readiness for lifelong learning [3, 4, 6].

Consequently, study programs place greater emphasis on personal skills and increase their use of active learning methods, e.g. design projects and case studies [5].

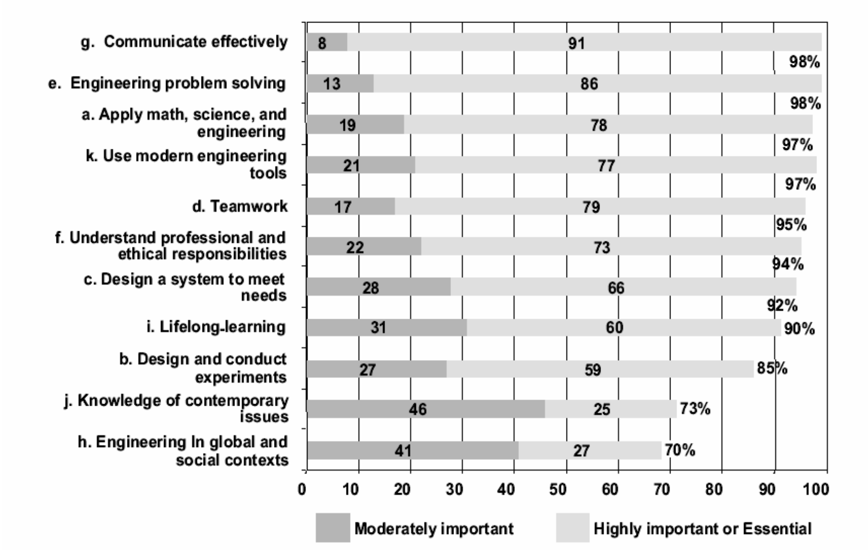

Figure 1 Importance of competencies based on EC2000 [4]

Design projects are the preferred method to enhance the above-mentioned competencies [3, 5, 6]. Projects sustain the fundamental technical knowledge, but also strengthen skills of communication, problem solving, teamwork or interdisciplinarity [5].

A student-centred instruction that requires students to work individually and in groups and demands more responsibility from them than in traditional lectures supports their intellectual growth and a deep approach to the subject matters leading to the desired understanding. Project learning confronts students with the need for identifying and formulating problems, making judgements and justifying them, generating ideas and further high level tasks that can be typically used in engineering courses [7]. Students working in teams influence their personal and communicative skills positively. They demand positive interdependence, individual accountability, face-to-face interaction, appropriate use of interpersonal skills and regular self-assessment of group functioning [7].

Based on these fundamentals and with the didactical appeal in mind that student-oriented learning is a concrete utopia that cannot be realized right away but only in small steps [8], the IKTD started the experiment to implement project learning in the exercises of engineering design and to find a balance between sometimes desired contradictory competencies and available temporal and mental capacity of students and supervisors. Main focus were the competencies in the fields shown in Figure 2.

The professional competence is of high relevance in every subject of the basic studies in engineering. Students of engineering design must learn to design, analyse and calculate certain machine elements not only for their success in exams but also for their professional career. Therefore, the projects were based on a technical task that requires and improves these skills.

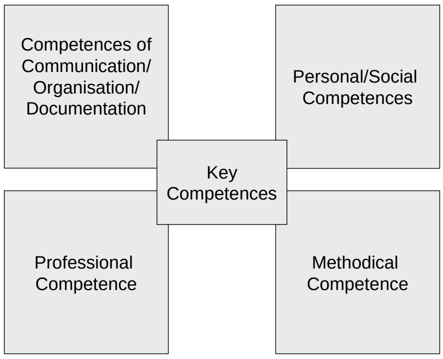

Figure 2 Focused key competences

Methodical competence particularly incorporates the ability to recognise and analyse technical problems, to plan a way to solve problems, find an adequate solution and to reflect the chosen approach critically. The project task was formulated as less constricted as possible and the choice of the solution approach was left to the students to improve methodical competences, although the supervisors were ready to prevent dead ends with a high amount of workload. The project task was enriched by a particularly methodical part that required the use of diverse methods from engineering design like requirements list, brainstorming or function structures.

The advancement of personal and social skills primarily aims at the qualification for teamwork. Students have to learn to arrange duties and to ensure their performance. This particularly includes an open-minded atmosphere within the teams, the ability to recognise and improve strengths and weaknesses and to cope with conflicts. The students were purposely thrown in at the deep end to gain real work experience and the teams were assisted by the supervisors if necessary. Professional support by a didactic institute for learning social competences is planned for the future.

Communication, organisation and documentation are an integrated part of the project task. They must be supervised and supported intensively, because it is the student’s first project. A professional, intensive and effective communication was supported by the compulsory use of journals and the preparation of e.g. interface protocols. The presentation skills were encouraged by two presentations with compulsory individual parts. The students had to plan their shared and their individual workload in advance and to compare it to the real working hours at the end. The project documentation followed professional demands, but was reduced in the extent. Students were supported by introductory seminars, the preparation of forms and a continuous supervision.

3 LEARNING ENVIRONMENT AND PROJECT ORGANISATION

About 200 students in the fields of “Mechanical Engineering” and “Automotive and Engine Technology” have to take four obligatory courses in machine design (“Konstruktionslehre”) in their undergraduate studies. Design lessons consist of lectures and traditional exercise courses in the first three semesters, Figure 3.

Course 1	Course 2
Fundamentals: •Technical drawing •Basics of methodology •Basics of mechanics •Basics of embodiment design	Joining technology: •Welding, bonding, soldering •Bolted joints •Springs •Rivets and pins
Course 3	**Course 4**
Drive technology: •Axles and shafts •Shaft hub connections •Tribology, bearings •Sealing technology	Drive technology: •Clutches and brakes •Gears •Traction drives •Hydraulics

Figure 3 Topics

The lecture in the fourth semester is supplemented by a project exercise. This machine design project covers mainly the topics of drive technology in the fourth semester and is based upon a module consisting of gears and clutches/brakes. The period specified for the project is usually 13 weeks with formally 2 exercise lessons per week.

Project teams usually consist of six students. They were advised to choose one team speaker responsible for meeting deadlines, a quality and documentation manager who is responsible for preparing and organising presentations and documentation. The teams were free to arrange the workload for the parts of the designed module, but everyone had to design at least one part and to check a different part designed by somebody else to gain as much experience as possible in different fields. The teams had to protocol content and results of their meetings and the process time of their tasks in a journal. Two presentations were set as important milestones in the middle and at the end of the process time. The task was finished by the handover of comprehensive project documentation with technical contents, e.g. drawings, calculations, parts lists and assembly instructions, as well as organizational details, e. g. journals.

The amount of mentoring must meet the students' demands as far as possible. The supervision team of 13 tutors consists of six research associates and two chief engineers supported by five advanced students. Lecture rooms were open for at least 12 hours a day, computer room access was even possible at night, and the motivation in many project groups also resulted in working hours literally round the clock and regionally distributed. Supervision is limited to (already extended) "office hours". The information and supervision of the students is, therefore, limited to several columns: lectures, a weekly seminar in the classroom, weekly group meetings, consultation hours on short call and response to emails that were additionally collected and distributed in the internet as FAQ. The introductory seminar provided an extended knowledge of the design and analysis of the demanded machine elements as well as information about organisational matters like project planning or presentation techniques. Weekly meetings were organized as report meetings important to notice the success, the keeping of the time plan and actual problems of the teams.

4 PROJECT TASK

The problem given to each team of students must meet several conditions. First of all it must be from the subject area and deal with drive systems and components.

The overall problem size must be manageable but not trivial. This is assured if the problem can – by mere planning – be broken down into subproblems manageable by a single person in a time frame of adequate size.

Examples are a trolley hoist of a bridge crane which had been given as a problem in 2003 and 2007 (problem originally provided by Engineering Design and Methodology (KTEM) of Technische Universität Berlin) and a façade elevator for cleaning windows which had been given as problem in 2005. Each problem confronts the teams with a number of trade-offs to decide. For example, a bigger hoist drum will have repercussions on other parts of the system e.g. the mounting of the hoist drum or the planetary gear inside of it. These topics need to be discussed by the teams.

5 PROJECT EVALUATION AND LESSONS LEARNED

All courses are evaluated by the students enrolled each semester by standard forms. The results for summer 2005 when students were working as a team of six on one project in their fourth semester can be compared with the winter 2004/05 when each student was working on six standard design problems in his or her third semester. The results of the evaluation of the 2005 project were then implemented and tested in the project in 2007.

By the end of the project in 2005 the students coached by each tutor where asked to appoint a spokesperson. These eleven students met with the professor being responsible for the course, the chief engineer being responsible for the organisation and the engineers who had come up with the problem. Students gave their opinion about the course and suggested improvements.

The approach of having a problem solved by a team of students was assessed favourably. The chance to use knowledge acquired in other subjects and to try one's hand at teamwork was mentioned in that context as was the experience of going all the way through the development process and working on a design more complex than one person alone could handle.

The workload was deemed too large. Other subjects required could not be studied with due thoroughness. In addition to that the workload was unevenly distributed within the groups because the members lacked the experience to estimate the work packages correctly. An indication of the relative size of work packages was asked for. It was strongly criticised that not all students working on the project could work on a type of subassembly which might be subject of the exam. Students also commented on the group dynamics they had observed. Slow students did hinder the advancement. Some team members did not honour agreements. In general the coordination of several peoples work was considered to be an interesting task but one needing planning.

Based on the evaluation the following design project was planned with a modified didactic approach. The main target was to ensure equal learning opportunities for all students. Since the course in question is not graded but prepares for a graded exam the main concern was that all students enrolled should be equally prepared for the exam.

Thus the project in 2007 was organised differently to meet the students' requirements. As an educational novelty the design task was split into a commonly solved and a specific individually solved part. It was therefore decided to have one of the transmissions and one of the brakes of the trolley designed by all team members before the actual start of the project. Also, some subject matter was shifted into the preceding course. Regrettably the project time had to be cut accordingly from 14 weeks to eight weeks. Organising a project and experiencing the related problems ought to be part of a project, too. However, relieving the students of some of their clerical duties by providing adequate forms facilitates the process and hopefully makes the result more accurate while still allowing for learning from failure. Since all these measures not only accelerate the project but also reduce complexity two more students were added to each team. This should speed up progress but also increase communication overhead, so that

the overall complexity will stay on a level sufficient for a lasting learning experience. To ensure that all team members deal with mechanical design problems four different students were responsible for the design of one subassembly each and the other four students were each responsible for the examination of the design of one subassembly.
During the project work the effort and workload was monitored more closely than before. Planning forms collecting comparable tallies from all groups have been prepared. Correctly appraising the success of each team remains a challenge.
The evaluation of the 2007 project shows that the main complaints of the students were improved sufficiently. The students felt particularly better prepared for the exam than the preparation for the exam was evaluated better than in the first two courses.

6 CONCLUSION

Many lessons were learned in the preceding projects. Giving projects as problems to be solved in a team is challenging for students and tutors. Since students benefit from projects very much projects ought to be part of exercises in the future. While there is room for future improvements the limits of what can be achieved in a limited time frame in the fourth semester must not be disregarded.
The educational novelty of dividing the project task into a commonly and a individually attended part turned out reasonable.

REFERENCES

[1] Accreditation Board for Engineering and Technology (ed.): Criteria for accrediting agentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik e.V. (ed.): Fachspezifisch ergänzende Hinweise zur Akkreditierung von Bachelor- und Master-Studiengängen des Maschinenbaus, der Verfahrenstechnik und des Chemieingenieurwesens, 2005 (ASIIN e.V., Düsseldorf 2005)

[2] Longmuß, J.: Projektarbeit in der Konstruktionsausbildung – Organisation und Bewertung. 1998 (VDI, Düsseldorf)

[3] Lattuca, L., Terenzini, P., Volkwein, J.: Engineering Change: A study of the Impact of EC2000, Executive summary, 2006 (ABET, Baltimore)

[4] Volkwein, J., Lattuca, L., Terenzini, P.: Engineering Change: A study of the Impact of EC2000, Int. J. Engng Ed. Vol. 20, No. 2, 2004

[5] Eyerer, P.: Theoprax – Projektarbeit in Aus- und Weiterbildung, 2000 (Cotta`sche Buchhandlung Nachfolger, Stuttgart)

[6] Felder, R., Brent, R.: The intellectual development of science and engineering students, 2. Teaching to promote growth, Journal of Engineering Education, 93 (4), 2004

[7] Meyer, H.: Leitfaden zur Unterrichtsvorbereitung, 1993 (Cornelsen, Frankfurt)engineering programs. Effective for Evaluations During the 2006-2007 Accreditation Cycle, 2006 (ABET, Baltimore)

[8] Akkreditierungs

Robert WATTY
Universität Stuttgart
Institute for Engineering and Industrial Design
Pfaffenwaldring 9
70569 Stuttgart
Germany
robert.watty@iktd.uni-stuttgart.de
+49 (0)711 685-66040

Hansgeorg BINZ
hansgeorg.binz@iktd.uni-stuttgart
+49 (0)711 685-66055