INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7 & 8 SEPTEMBER 2017, OSLO AND AKERSHUS UNIVERSITY COLLEGE OF APPLIED SCIENCES, NORWAY

# DESIGN PROJECTS IN UNDERGRADUATE COURSES– APPROACH AND EXPERIENCES

**Robert WATTY**
Hochschule Ulm, University of Applied Sciences

**ABSTRACT**
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". 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.
This paper describes theoretical background, planning and implementation of design projects, their allocation in the bachelor program of mechanical engineering at the University of Applied Sciences in Ulm, experiences and consequences drawn for future projects.

*Keywords: Project Learning, Design Education, Design projects, Internationalization at home.*

## 1 INTRODUCTION

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.
Actual and future markets in a globalized world are developing fastly and challenging companies in all fields of technology. Therefore innovations (= new and economically successful products) are a prerequisite for enterprises in order to be successful and competitive in these markets. Furthermore most products require the interdisciplinary combination of e. g. mechanical, electronical and software components. Companies require engineers with advanced knowledge in these fields and ideally with a "entrepreneurial" spirit and some skills beyond pure technical knowledge.
Thus 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.
The author started teaching projects at Ulm University of Applied Sciences in 2011 and implemented about 15 internal projects and 5 projects in cooperation with companies. Actually projects are extended towards tasks given by companies an projects in international cooperation towards the end of the study programs.

## 2 EDUCATIONAL REQUIREMENTS

### 2.1 Accreditation criteria

According to the requirements of accreditation boards, programs in mechanical engineering should ensure, that students "apply principles of engineering, basic science, and mathematics …; to model, analyze, design, and realize physical systems, components or processes; and prepare students to work professionally in either thermal or mechanical systems while requiring topics in each area" [1].
After finishing mechanical engineering programs, students must be able to work professionally in an engineering environment and to "identify, formulate and solve engineering problems" under typical boundary conditions [1] and to apply and extend their knowledge independently [2].

## 2.2 Employers requirements and didactic conclusions

Employers ratings of the importance of EC2000 accreditation criteria [3], figure 1, show, that 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 [4, 5, 6].

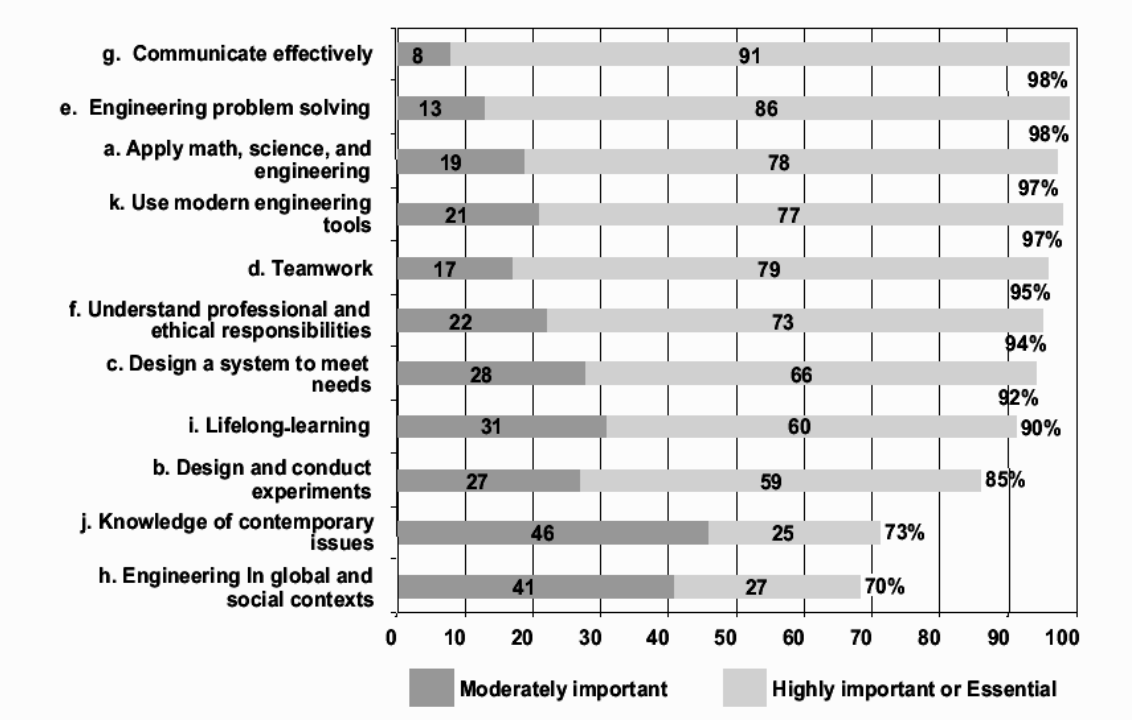


*Figure 1. Importance of competencies based on EC2000 [3, 7]*

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].

Design projects are the preferred method to enhance the above-mentioned competencies [3, 5]. Projects sustain the fundamental technical knowledge, but also strengthen skills of communication, problem solving, teamwork or interdisciplinarity [5, 7].

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, figure 2.

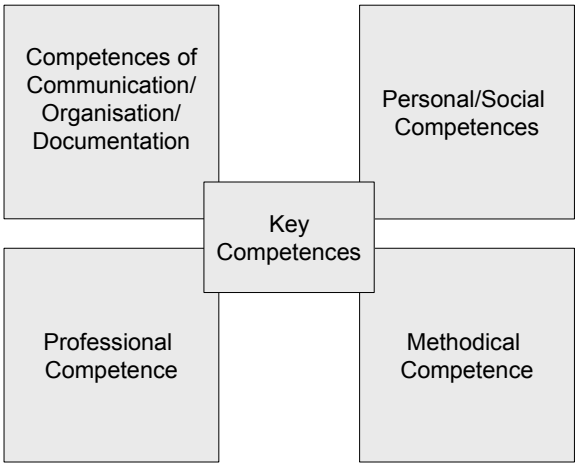


*Figure 2. Focused key competences [7]*

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 [6]. 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].

- 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.
- 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.

Moreover, engineers in modern, innovative companies need some entrepreneurial knowledge, although they are using it working as employee within a company (interpeneurship) and they need to know the basics of innovation management as well. This leads to the $i^5$-skills-approach based on Geraedts [8], figure 3.


*Figure 3. Advanced competencies: $i^5$-skills-approach based on Geraedts [8]*

- Engineers increasingly need international experiences in a global economic world. Thus it is essential to support students in improving their language skills, their intercultural knowledge and their ability to communicate in international teams or internationally distributed projects. The most effective way of getting international experience is working in foreign countries. Alternatively students can be confronted with "internationalization at home" by inviting teachers from foreign countries, lecturing in foreign languages (preferably English), involving international students or organizing international projects in cooperation with partner universities or companies from other countries.
- Modern technologies are typically interdisciplinary and involve the combination of knowledge and technologies from diverse disciplines. Engineers must be able to determine the interfaces between their area of expertise and other disciplines and to define these interfaces, their interdependencies and their mutual requirements. Therefore they must have a basic knowledge of

neighbouring disciplines, to be able to understand project partners from other disciplines and to communicate successfully with each other. Project tasks for mechanical engineering students should include aspects of other disciplines like economy, software engineering, electronics or even ethical or social questions.

- Technological and economical success depends on innovative products. Students must acquire basic knowledge about patents as well as methodological approaches to develop innovative products. Therefore tasks of projects should require the solution of largely untackled problems.
- Entrepreneurship is important for national economies and provides great chances for young engineers. Entrepreneurial thinking is also important for a successful career of engineers within companies, here called "Interpreneurialship". Nevertheless it is often not taught in engineering programs. Lectures can be expanded to teach basic questions of company foundation, project tasks can request parts of it like setting up a business plan, visiting fairs, presenting ideas to potential sponsors or even providing a business incubator as a university.
- Interpersonal skills include advanced knowledge about communication within teams, companies or towards customers and public, team leadership and other skills needed for successful implementation of complex projects. They can be encouraged by setting up a realistic and challenging environment for student projects e.g. in cooperation with companies.

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, the author implemented project work with increasing autonomy of the students during the first two years of an undergraduate program in mechanical engineering. Main focus was the basic competencies in the fields shown in Figure 2. This approach was broadened to the advanced competencies of the $i^5$-approach described in Figure 3 in the 3rd and final year of the program.

## 3 EXAMPLES OF PROJECTS IN UNDERGRADUATE COURSES

Figure 4 shows the structure of the courses teaching Machine Design and typical projects within course 2 to 4. Students have to solve technical problems in teams of 4 to 6 and to organize their work and their internal communication. Tasks are more detailed in the lower and become more open towards higher courses. The content is based on the lectures of the given semester.

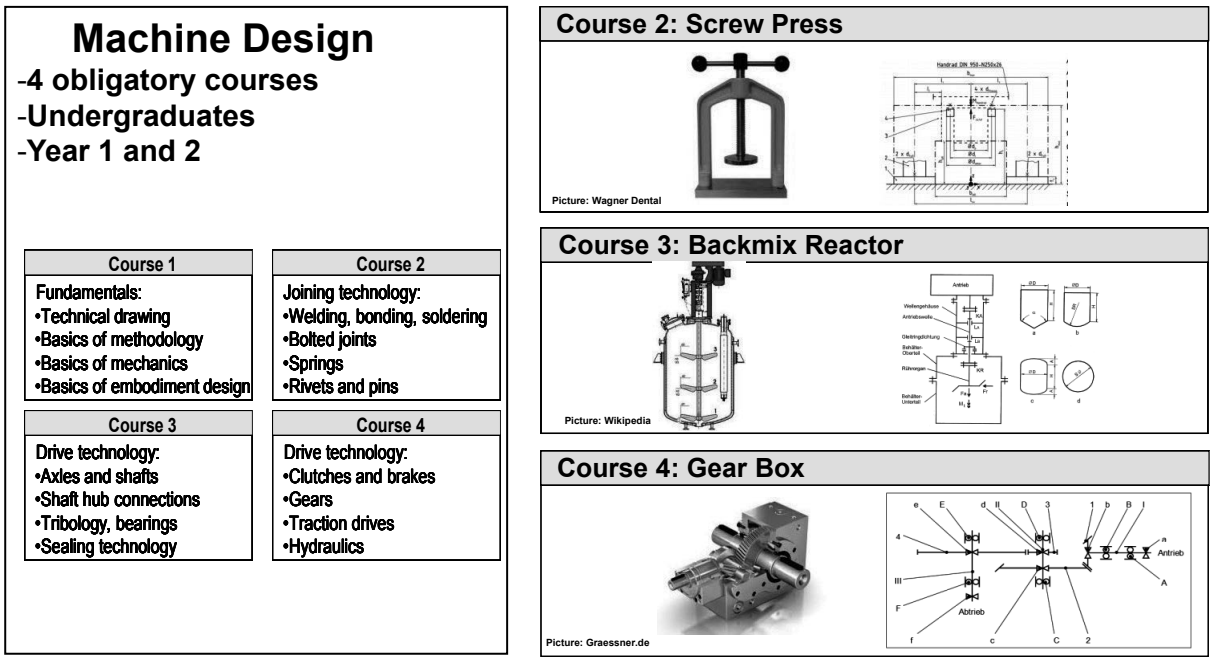


*Figure 4. Typical projects for fundamental competencies*

Courses on "Design Methodology", figure 5, take place in the second half of year 2 (parallel to Course 4 in Machine Design). Students, in teams of 4 to 6, have to complete a more general task ("Refrigerator for Africa") starting with finding out the requirements and planning their approach to solve the problem and going on to find a principle solution, define the construction structure and

document the solution. The task is usually given by a company and based on existing products that have to be adapted to modified needs, new groups of customers or different technical demands. Students have to communicate with the company and to present the results at the end of the project. Projects in the "Design Seminar" go even further. The task, given by companies or worked out by students, has to be innovative and the solution has to be patentable. Lectures teach about the needs for patents and students (again in groups of 4 to 6) have to start with a patent search and to find new solutions.

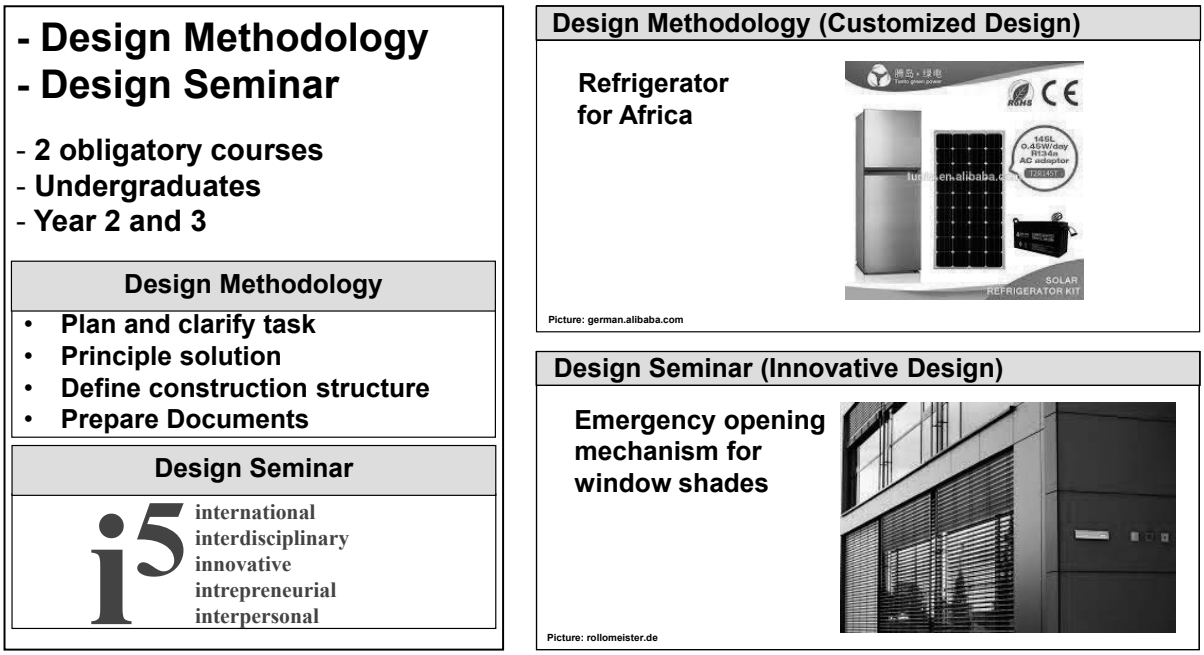


*Figure 5. Typical projects for advanced competencies*

One course in gear box design is actually given in an international group in cooperation with a partner university in Finland. Students have to design a gear box and prepare the documents for manufacturing that is done in Finland and vice versa. This approach is actually planned to be extended to the "Design Seminar" to work in mixed groups from three countries (12 students distributed in Finland, The Netherlands, Germany) to solve a problem given by a company in one of the countries where the solution is presented in the end. Students have to organize the work for the whole team, to communicate and to make sure that documents are spread actually to all members of the team.
Thus all students in mechanical engineering get a "Internationalization at home"-experience and have to get at least a little bit of international experience.

## 4 CONCLUSION

The experiences with design projects indicate:

- Project-based learning allows the successful integration of key competencies in undergraduate courses for engineering design students.
- The identification of students with their task results in high motivation. They describe the experience of a completed design process as interesting and useful.
- Project based learning stresses the social abilities of students and can even be used to support intercultural competences.
- The workload for students in projects is high and requires careful planning within the student groups and autonomous and reliable cooperation of all students in a group. Projects enable students to work autonomously within a team.
- Documentation and presentation of process and results gives students the opportunity to reflect and improve their approach in order to enhance soft skills.
- Project-based learning requires intensive support by supervisors. Teaching changes from a teacher-up-front-style of instruction towards mentoring and supplying framework conditions for autonomous learning.

- International cooperation of universities and companies opens up new ways of teaching and give students the chance to experience “internationalization at home”, to work on distributed and realistic tasks and to collect some “practice” during their study programs.

## REFERENCES


[1] Accreditation Board for Engineering and Technology (ed.): *Criteria for accrediting engineering programs. Effective for Reviews During the 2016-2017 Accreditation Cycle*, 2015 (ABET, Baltimore)

[2] Akkreditierungsagentur 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*, 2011 (ASIIN e.V., Düsseldorf 2011)

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

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

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

[6] Toth-Teglas, T.; Hledik, E., Fonadova, L.*: An analysis of Employer Requirements of University Graduates.* Acta Politechnica Hungarica, Vol. 13, No. 5, 2016, Hungary

[7] Watty, R.; Binz, H. *Project-based learning in undergraduate courses at the University of Stuttgart – experiences and challenges.* International conference on engineering and product design education (E&PDE), 4-5 September 2008, Barcelona, Spain

[8] Geraedts, H.: *Innovative learning for innovation.* PhD-Report, 2010, Kessel/NL