INTERDISCIPLINARY, INTERNATIONAL AND INDUSTRIAL COOPERATION EFFORTS WITHIN THE MECHANICAL ENGINEERING DEPARTMENT

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ABSTRACT

Cooperation is a multi-faceted concept in higher education. It could denote the cooperation between industry and academia, enabling students to train problem solving in a real life context. It could also describe the internationalization efforts found in teachers' and students' exchange programs. Moreover, cooperation exists between disciplines in order to enable a holistic perspective on course contents. This paper describes experiences of teaching some courses where all these aspects of cooperation are utilized for reaching the best possible conditions for teaching. The courses are within Machine Design, Product Development, Project Management, and Degree Project, and are all taught in English and contain projects in cooperation with industries. These courses are dealing with different approaches to the industrial projects to give the students an overall view and understanding of the real engineering work. The practical work is in form of student driven industrial projects, where students from the Mechanical Engineering Department at Linnaeus University collaborate with international students. The industrial related projects results in valuable real life experiences. The background of students from different countries and experiences of international teachers enriches the teaching process and students' teamwork activities. Another result is the valuable culture exchange between the students and teachers which gives skills for future engineers to work in the European or global labor market. The implementation of the courses is described with focus on how cooperation between industry and academia, as well as between different competences at Linnaeus University and the University of Rousse, Bulgaria are utilized for creating optimal learning conditions.

KEYWORDS

Interdisciplinary cooperation, international cooperation, industrial cooperation, project based education, heterogeneous student groups, Standards: 2, 3, 4, 7, 8

INTRODUCTION

Nowadays, the labor market for engineers is not restricted by the national borders, the global economy and the multinational industries in combination with their suppliers are demanding new skills and experiences of engineers besides the technical skills and knowledge. The workplace situation of engineering professionals has changed over the last two decades. Engineering education crosses borders and engineering professionals work globally facing different cultural workplace background. Rapid changes in technology and the internationalization of engineering education have forced increased attention on engineering professional skills. As a result, there is a strong need to revise the soft skills of engineering profession and to include global skills in the engineering criteria, Patil (2005).Globalization influences the shape of education at technical universities and creates it as the carrier and distributor of general knowledge and research result, Szpytko et al. (2007).

In this paper, the authors are presenting how some of the educations at mechanical engineering department at Linnaeus University LNU in Sweden is arranged to fulfill the requirements and demands of the labor market for industries attracting mechanical engineers. The focus of this paper is on how some courses offered for the own and international students including industrial projects are organized and carried on in order to achieve the goals of interdisciplinarity, internationalization and real-life problem based education.

WHAT IS COOPERATION?

In this section, cooperation will be explored in terms of interdisciplinarity, internationalization and industrial collaboration, but let us start with defining the term. According to businessdictionary.com, the word cooperation could be defined as:

> *"Voluntarily arrangement in which two or more entities engage in a mutually beneficial exchange instead of competing. Cooperation can happen where resources adequate for both parties exist or are created by their interaction"*

In the context of this paper, cooperation is between academia and industry in an international environment where program and international student are educated by own and international faculty through real life industrial project. The cooperation thus exists between faculty members as well as students in the class room, and between industry and academia, creating a complex pattern of different exchanges and interactions. In the following, we will defined these types of cooperation, and in the end of the section, a summary is provided in Duffield et al. (2012) note that partnership and collaboration, both internally and externally, have become popular in higher education, but also point out that the institutions of higher education are not designed for such cooperation activities. Institutions are traditionally autonomous and the typical mode of work is side-by-side rather that in collaboration)

Interdisciplinary cooperation

Interdisciplinary cooperation is the integration of two or more disciplines in the education, Davies and Devlin (2007). The level of interdisciplinary spans from offering elective courses from a variety of disciplines, to the total integration of different disciplines by dissolving institutional borders. The normal mode is something in between. A similar definition is used by Pharo et al. (2012, p. 498):

> *"…the integration of disciplinary perspectives to produce insights that are more than the summing of disciplinary knowledge"*

Davies and Devlin (2007) note that the term 'interdisciplinary' is often confused with similar terms such as 'multidisciplinary' and 'cross disciplinary'. Multidisciplinary means that multiple, discrete disciplines co-exist without any or few points in common. In cross-disciplinarity a topic outside a field of study is investigated, but no cooperation between the disciplines exists and no transfer of methodologies occurs. Meaningful interdisciplinary collaboration brings together expertise from different subject areas so the fundamental building blocks of a given discipline are clarified, at the same time as its complementarity with one or more other disciplines is described. By utilizing the strengths of each area, a synergy effect appears, and the interdisciplinary cooperation leads to higher level of knowledge than any one area could produce alone, Waterman et al. (2011).

Interdisciplinary cooperation includes, according to Waterman et al. (2011), dimensions of interprofessional education, students' experiential learning in co-ops, internships, community-engaged projects; working across academic disciplines; working between academic and professional/community contexts; working across the sub-disciplinary fault lines within a unit; diversity of background, age and experience.

Waterman et al. also recognize these characteristics of interdisciplinary cooperation:

- entails intentionally wanting to know and understand another's discipline;
- involves cooperation, good communication, listening, and trust;
- requires a personal commitment to learn the terminology and frames of reference of another discipline;
- demands new skills, such as negotiating across these lines;
- fosters understanding, humility, curiosity, and respect;
- necessitates learning to embrace the other's perspective;
- promotes knowledge of one's own disciplinarity, enculturation, and beliefs.

Duffield et al. (2012) report on lessons learned from a cross-institutional project in Valley, USA. They bring forward four points as being crucial for success. The first is a clearly defined governance model with policies and procedures followed by all institutions involved. Moreover, building partnership takes time; therefore it is of highest importance that people involved are released from normal responsibilities. The people to be involved should also be carefully chosen and given possibilities to meet face-to-face so trust could be built up. Finally, it is important that the cooperation is mutually beneficial for the partners. The experiences of Pharo et al (2012) are the similar when reporting on a teacher collaborator project at the University of Tasmania. The collaboration was successful during the initial year when the project was supported by a part-time network facilitator. The collaboration was hard to maintain after the initial year though, when the facilitator function lacked funding. The teachers felt being time-poor and overworked, and the participants were unable to dedicate the time required to continue. Pharo et al. points out that there is a need for recognition of the benefits for justifying these kinds of collaboration efforts.

International cooperation

According to Knight, quoted in Delgado-Marquez et al. (2013), internationalization is "'the process of integrating an international, intercultural or global dimension into the purpose, functions or delivery of postsecondary education''. This definition is only one of several existing, and consequently there are several ways to measure internationalization in form of key performance indicators, Delgado-Marquez et al. (2013). The incentives to work with internationalization are several. Well recognized universities uses it as a means to keep positions, while others use internationalization as a means to become world-class institutions, Tadaki and Tremewan (2013). This relationship between reputation and internationalization has recently been confirmed in research: Delgado-Marquez et al. (2013) found a positive connection between internationalization and a university's reputation. Moreover, quantitative benefits, such as economic growth, as well as quantitative, such as offering diversity, are also motives for working with internationalization. Matijašević, and Carić (2009) argues that exchange students are the most important element for long-term strategy leading to a stable political, economic, and competitive advanced multinational society. A term closely related to internationalization is globalization. Marginson and van der Wende (2007) connect the term globalization to the integration of national systems while internationalization stands for the interconnection of national systems. From this perspective, internationalization could be viewed as a way to gain knowledge of cultures and national differences without altering your own national identity.

International cooperation can be manifested in several ways, and common characteristics are the close relations and cooperation that are built between institutions, Matijašević and Carić (2009). Cooperation can be established on university level as well as on faculty level. Spencer-Oatey (2012) lists following mechanisms of internationalization:

- the recruitment of excellent staff from around the world;
- the promotion of international research collaborations;
- the encouragement of staff mobility, such as via sabbaticals at universities in a different country and via attendance at international conferences;
- the development of joint degree programs.

Industrial cooperation

Researchers as well as practitioners have debated the role and objectives of higher education with respect to why and what type of knowledge that should be acknowledged as important. It is often proclaimed that academia cannot meet the needs of industry, Elkamel et al. (2006), Witt et al. (2013). Nonetheless, universities and industry have been collaborating for over a century, and the rise of a global knowledge economy has intensified the need for these kinds of partnerships. Edmonson et al. (2012) points out four areas of governmental focus for succeeding with creating strong industrial partnerships: long term strategic plan and funding, the autonomy of universities to form the partnership programs, reward to active, strong and effective partnership programs, and strive for excellence, i.e. promote the best universities. In a communication presented by the Commission to the Council and the European Parliament (1992) industrial cooperation aims at three major objectives:

- faster industrial application of the results of fundamental research
- improved output of technical skills
- more effective transfer of technology between sectors and regions.

Continuingly, the cooperation should be adopted where all partners agree that it leads to results otherwise not achieved.

Thune (2011) found several industrial related cooperation activities applied by four regional institutions in Norway: financial support to strengthen competence and support in form of equipment, cooperation in the development of new education programs, joint research and development activities, and activities intended to support the students' transmission from academy to employment. From the practical perspective, there is a strong need to bring real world experience and insights into classroom, Elkamel et al. (2006). Something all four institutions in Thune (2011) had in common was the support from industry to accomplish the study programs in form of project papers, term papers and main projects. In the communication of the European Commission referred to above, education and training projects were seen as an effective means for cooperation, as they provide a way to address real business problems, both short and long-term.

EDUCATION WITHIN THE MECHANICAL ENGINEERING DEPARTMENT

The Mechanical engineering department at Linnaeus University offers three first cycle programs and two second cycle programs. Two of the first cycle programs are engineering programs (within Mechanical engineering and Industrial engineering), while the third is a Bachelors program in Industrial Management. The first cycle programs comprise 3 years (or 6 semesters), which equals 180 ECTS. For the second cycle, the department offers a one-year Master within Mechanical Engineering with specialization in structural dynamics, and a two-year program within Industrial Management with specialization in sustainable production.

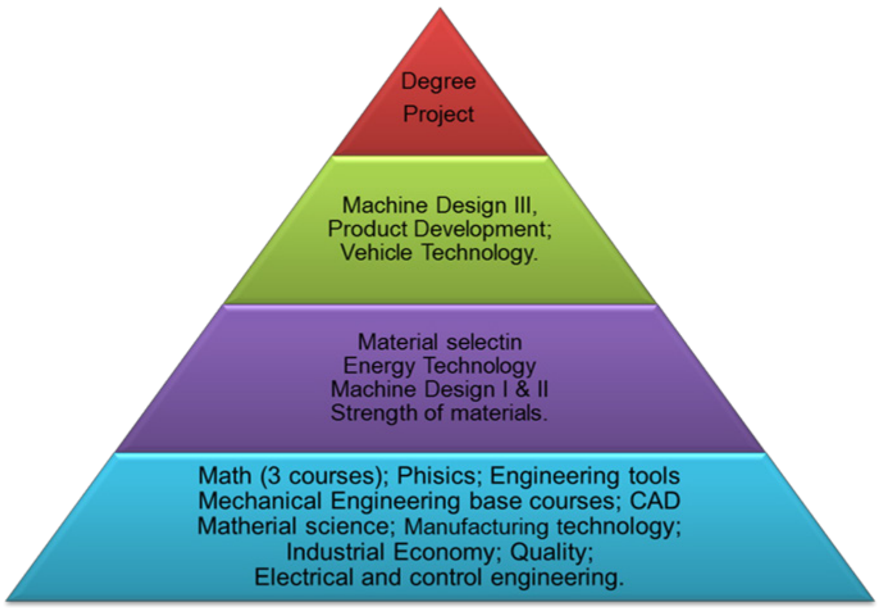

Figure 1. Courses at the Mechanical Engineering Program at LNU, divided into 4 levels

The courses described in this paper are mainly taught in the three-year Mechanical Engineering program. Therefore, the structure of the Mechanical Engineering program will be briefly described in the following, also see Figure 1. Basic courses within mathematics, physics/mechanics, engineering tools and the like are taught in the beginning of the program to give the students enough knowledge to carry on with the mechanical engineering fundamental courses, like Strength of material, Machine Design etc., in the second step. The third step offers specialization in product development, advanced machine design, and vehicle technology. The education is ended with a degree project (final project), which is in fulltime work of approximately two months. Each course, except the degree project, are of 7,5 ECTS, while the degree project is on 15 ECTS.

The students carry out at least one industrial project per semester. The industrial projects in the first and second level are rather small but form the backbone of the courses in the last year. Table 1 lists the courses which include industrial projects and provides information about the project purposes and contents. The program is in Swedish, but some of the courses are offered in English and enroll both Swedish program students and international students. The purpose of this setup is partly to attract international students to our university and partly to give all our students who do not have possibility to study abroad a possibility to take course in English in an international environment (Program and international students are mixed together in project groups). This is called internationalization at home. The courses taught in English which include industrial projects are Machine Design I, Product Development, and Degree Project (final project). These courses will be described in more details in the further. In addition, a course taught in the second semester of the first cycle program in Industrial Management, Technical Projects and Report Writing, will be described. This course depicts how international and industrial collaborative education is designed for basic level courses. The course was also picked because it is a mandatory course for international students wanting to complete a degree project within Mechanical Engineering.

Table 1. The industrial projects and their progression in the mechanical engineering program

Semester	Course	Industrial Project Purpose and Contents
1	Mechanical Engineering base course	The purpose of this project is to learn about the company's products, production methods, organizations etc. Each student has to spend at least 5 whole days at the host company to work with production. After that, the students have to write reports from their experiences answering questions (according the tasks) and to make oral presentations in the classroom.
2	3D-CAD	The idea in this project is to make 3D-Cad drawings in an acceptable difficulty level from industrial products. 2D drawings can also be generated from the 3D-drawings.
3	Quality	This industrial project did not start yet, but the idea is to study quality system of the host industry and to make different time of measurements and to compare the result with the requirements.
4	Machine Design I (In English)	The desire here is to find projects which include easy calculations of material strength with respect to static, fatigue, or impact load. Also calculations on screw or welded joints are also desired. Simple drawings and sketches can be included in these projects as well. Reports and oral presentation are required. The project makes 20% of the course. So far, the same projects has been also used in a course "Selection of Material and production Methods" to continue with the material and production method selection.
5	Product Development (In English)	The purpose of this course is learning about the product development process and how to apply it in real product project. It is also about project management and communication using technical knowledge from previous courses to solve the problems. The course is project-based with some compulsory lectures and seminars. The most of the schedule time is about supervising and feedback. This course does help students to plan and accomplish their Degree Projects in the following semester.
6	Degree Project (In English)	Almost all the degree projects are carried on in the industry. The students are advised to work in group of 2 people in each group. They have to find projects by themselves, and when the projects are approved by the examiner, and then they have to make Gantt-chart which will be approved by the industry. When the work is processed, the student groups have to present the solutions in report and in oral where the faculty and industry people are gathered. The industrial projects here must be in the field of Product Development and/or Machine design or closely related areas.

COURSE DESIGN EXAMPLES

Technical Projects and Report Writing

Technical Projects and Report Writing is a basic level course on 7,5 ECTS. The course is mandatory within the Bachelor program Industrial Management, and is also offered for international exchange students. The student group usually has around 50% Swedish and 50% international students, and the international students do belong to different majors at the home universities. The course teaches industrial project management methodology and covers definitions, management, planning and follow up. It also teaches study methods and technical writing on academic level. The main part of student activities is connected to project-based work either directly or indirectly. In the beginning of the course, the students are randomly divided into groups of four by the teacher to ascertain that the groups contains a mix of Swedish and international students, first year and more advanced level students, and students representing different majors. The student groups are thus truly heterogeneous. The project groups thereafter formulate and plan a project of their own choice. Some years, the project should fit within a theme, but generally the freedom to choose project is high. The project idea is documented in a project plan and discussed during a seminar. Thereafter, the groups carry out the study quite independently, with support from scheduled course activities and supervision from the teacher. The results are reported orally in form of a presentation and in writing as a report. The students are also asked to report on their individual progress and give reflections on the project work and the course outcomes.

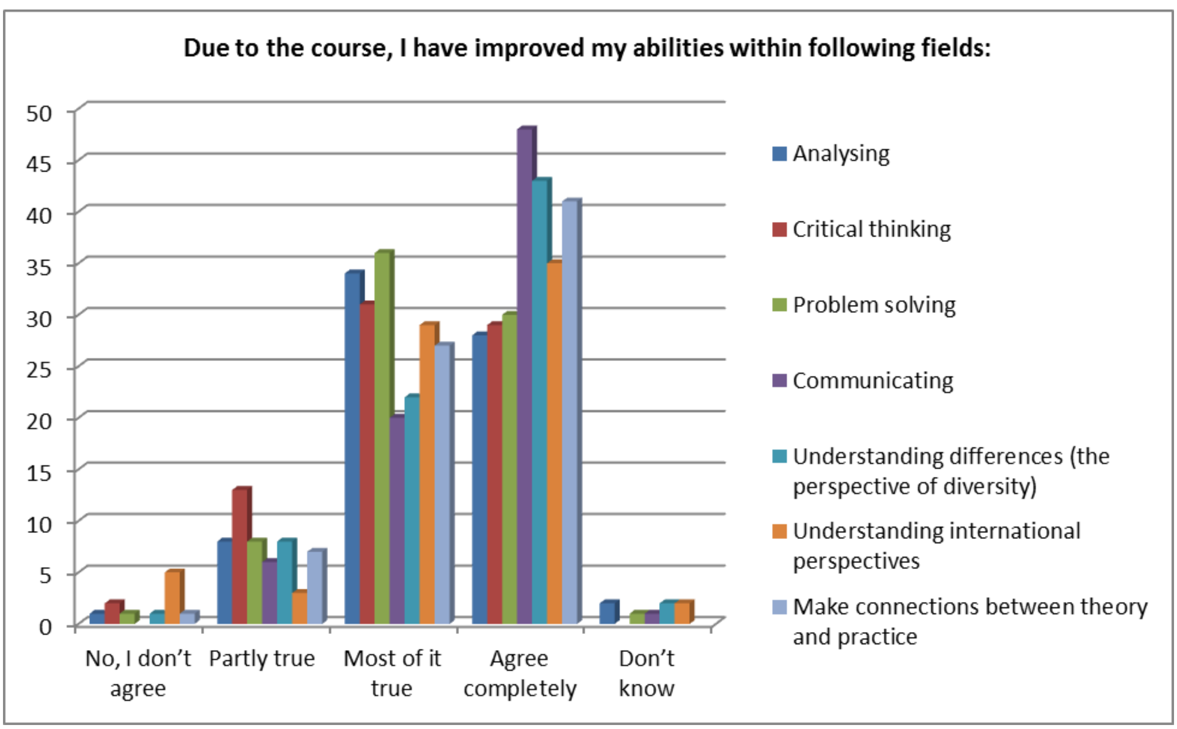

Figure 2. Student assessment of generic knowledge outcomes

Project work is in this course interdisciplinary, encouraging the use of individual students' competencies, and international, with high degree of cultural exchange, as the groups are encouraged to find their own way of organizing and work on group dynamics. The language skills are developed as the groups are forced to find effective ways to communicate. The projects are not forced to be industrial based though; we see a big spread of topics as well as study methods applied, spanning from theoretical literature studies to practical experimentation or product development. Working with industry we believe would require a more homogenous group of students and a clearly defined task formulation. Instead, we emphasize the experiences you gain from working in interdisciplinary and international contexts and provide a possibility to train the full problem solving circle, from idea brainstorming and definition to critical evaluation of the outcomes. The course evaluation confirms that the students apprehend that they gain relevant knowledge. In Figure 2 the results for one of the evaluation questions asking students to judge the improvement of seven generic skills are found. The answers are collected from the evaluations from years 2010-2013, in total 76 responses. The most developed skill is communication, followed by understanding differences and making connections between theory and practice. About half of the students also believe that their abilities in understanding international perspectives have improved.

Machine Design I

Machine Design I, as the name shows, is the first course in the field of machine design. This course is based on the knowledge of courses such as mathematics, physics, material sciences, technical drawings and CAD. The course contains dimensioning and design with respect to static-, fatigue-, and impact stresses. It is also dealing with mechanical failure theories and failure preventions. These theories are applied in the cases of power screws, bolts and screw joints as well as welded joints. An industrial project is also included. Usually, the industries are asked to provide student groups with projects which include force analyses, basic strength calculations, design and drawings, etc. For supporting the companies to select appropriate projects, the course responsible has developed a clear description for the industry about the course contents and objectives, and expected project level and topic. Usually, the students are satisfied with the projects, but is happens that the project task demands high level skills and/or require more time than what is planned in the course. Usually five students are working in each group. The student are free to select their group members, but with condition that the international students must be distributed equally among the groups, and international students from the same country are not allowed to be in the same group.

The course evaluation (comments and figures below are taken from last year's course evaluation) shows that the students were very satisfied with the projects in the course. As shown in the table 2, and it is well known among the teachers, most of the students like very much to work in projects from the industry. Some of the student comments regarding the projects are the following:

- "The project was the most positive part of the course because we had a chance to work with real problems."
- "We had a chance to work with the theory part at same time with applications in the projects. The engineering skills have developed in this course."
- "The project is the most interesting part because it was easier to understand and learn. It is exciting to solve problems for industries and to feel how it is to work as an engineer."
- "The design project included parts which required knowledge in higher level."

Nevertheless, there are always some problems that show up for one or few project groups. It can for instance happen that the project task require higher skills than the course offer, or the contact person at the company do not have time and/or do not show any interest to help students with their questions.

Table 2. Student assessment of the project work in Machine Design I

	1 (Low)	2	3	4	5 (High)	Total
Relevant	0	5	1	7	11	24
Interesting	0	4	3	6	10	23

Product development

The course Product development is a result of active international cooperation. It is carried on by two teachers one from Linnaeus University and the other guest lecturer from University of Rousse, Bulgaria. This is a consequence of the active international work among the Erasmus agreement between these two universities. The mission of the course is to prepare future leaders in new products´ engineering and management. Students need to have more knowledge and information except the formal theory provided according to the course syllabus. The course Product development is a real example of interdisciplinary cooperation: The students are using not only their previous experience in machine engineering education, but they also need some knowledge in marketing, project managing, decision making, report writing and so on. In product development education, project-based learning is essential in order to integrate the disciplines of design, marketing and managing of creating a new product. This course was planned to be taught as mainly project-based, supported with a number of lectures. A major industrial-related project thus form the main part of the teaching in form of industrial visits and meetings, group based work, tutorials and report writing. Besides the Swedish program students there are a big number of exchange students from different countries, like Germany, Netherlands, Turkey, France, Spain, China, Czech Republic, Mexico, and Poland, participating in the course. The student group is thus heterogeneous with respect to different cultural and educational background, although the students are disciplinary homogeneous as they all possess technical and engineering knowledge. The same group size and requirements as in machine design I are used in this course.

It is a big advantage to work in cooperation with the industry and to have real industrial projects; despite sometimes it is really hard to find the suitable type of projects as a size and a product. For the successful project work it is important that companies provide real problems, completely clarified and explained. This puts extensive stress on the course responsible to find suitable industrial projects, and much time is devoted for planning the course, communicate with industrial representatives and find challenging yet feasible projects within the time frame. The cooperation with the industry is also realized by inviting guest lecturers from the industry. There were two guest lecturers with industrial experiences invited to give a couple of lectures. One of those lecturers, an active engineer at a company in the region, showed the students examples from real project on his company. He also showed that he use to apply knowledge from a similar course that he participated in some years ago. This lecture was a really good inspiration for the students.

The course includes a number of lectures, but the most of the “teaching” time has been used for project supervising and student feedback. The diagram above (figure 3), which is taken from this year’s course evaluation, clearly shows that the students did like to work in project more than participating in the lectures. It is also declared very clearly (in the evaluation) that the majority of the students were very satisfied with the industrial projects and with the way of teaching. All the industries, except one, were highly serious in their relation with the students; they welcomed the project groups to visit the company and they always answered questions related to the project task. The Linnaeus Technical Centre (LTC) that acts as a link between the Linnaeus University and the industry in the region had arranged the projects for our students, and they followed the students' progress from the beginning to the end. The industries and LTC were very happy and satisfied with the outcome of the projects, which also increased the students' self-confidence. LTC asked for copies of the students' oral presentations to be used as example of successful co-operation between industry and academia.

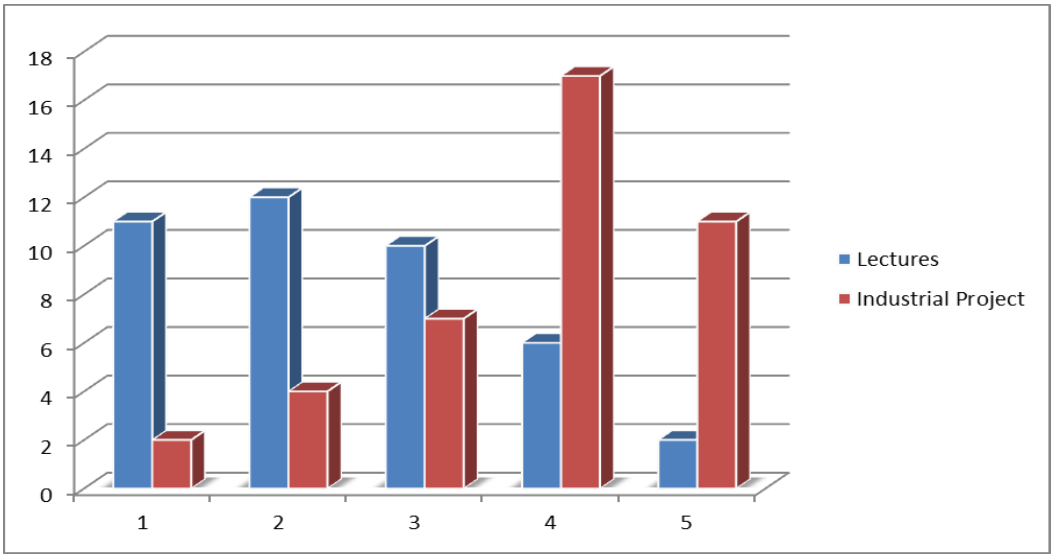

Figure 3. Student assessment of the teaching methods

Degree Project

The final project, or degree project, is a 15 ECTS assignment, which corresponds to 10 weeks of full-time study. The project is realized in the final stages of the program, usually in the second half of the spring semester of the final year (third year for the bachelor degree). The students do usually accomplish their project at industry or they take an industrial related project and accomplish the work at their university. This tradition is some decades old; therefore Swedish industry typically is good at providing engineering students at the final year with suitable and real engineering problems. When students accomplish their final project at industry, the project becomes a bridge between the university and industry or between their studies and professional work. Many times, the final project also becomes an entrance to the first job. Students work in groups of two to three persons and should find a suitable project by themselves. The university provides some general support in form of the industrial coordinator function, which enables industry to get in contact with students, and helps students as well as industry to find a suitable partner for a specific type of project. The project task and objectives are formulated by the students in cooperation with industry and academia, to ensure that all interest parts will reach their specific goals. When executing the project, students typically have one supervisor from academia and one from industry. The project groups are typically not mixing Swedish and international students, but those kinds of constellations have existed. The non-Swedish groups often require more help in finding an industrial partner due to less knowledge of the companies found in the geographical area and less experience in independent project work compared with the Swedish students. The region is characterized by small and medium sized companies, so reluctance from industry to work in other languages than the native could also be a reason.

The students appreciate the industry related projects, partly because they are “mentally” prepared and partly they see this as a good chance to get in contact with the industry, to show what they can, and to have a chance for future work. The students in general are also very satisfied with the course itself. In the evaluations, three main areas of strengths are mentioned: 1) the course design and administration, 2) the tutoring, seminars and feedback, and 3) the opportunity to apply knowledge and do “real” work in a company. The latter correlate well with the generic skills the students from the Industrial management program apprehend as being most developed during the course, namely Making connections between theory and practice, Problem solving and Communicating. Below some comments from the Mechanical engineering students are found:

- “It is very positive to have a chance to work with something you are interested of.”
- “It is positive to have the opportunity to apply the theories in real work.”
- “It has been very instructive”

CONCLUSIONS

Higher education is multidimensional and multi-purposeful process. Nowadays the globalization requires from the universities to be internationally connected to other universities abroad, using the opportunity for cooperation between institutions, teachers and students. Linnaeus University is a university with very strong international orientation. Usually about one third of the students attending the mentioned above courses are exchange students or free-movers from abroad. The possibility to work in a very close relation with the industry, having industrial projects during the study time and doing the final project at companies is appreciated by all of the students and give them the motivation that they receive a really good education. For some of the international students the study at Linnaeus university was the first change to work in the environment of education- industry cooperating. In the globalized knowledge economy, disciplinary as well as interdisciplinary knowledge is of importance. The integration of several viewpoints and disciplines in engineering education broadens the students’ minds and prepare them for the future profession, where the ability to understand as well as cooperate with different disciplines is required. This is enabled in the courses described by the cooperation of teachers, as well as students, from different disciplines.

One of the best ways of evaluating the knowledge acquired by students in engineering subjects is through application projects where they need to take theory to practice and put together all the concepts learned. This can only be achieved if the course essentials are well understood and properly interrelated; otherwise, students need to go back to theory and review the basic concepts. In consequence, evaluating a real project is, in a way, an evaluation of the entire course. In addition to absorb the concepts more efficiently, there are other collateral advantages of conducting projects: students typically learn to manage their time efficiently to meet deadlines, they work in groups where some social skills are required, and they are trained at writing technical reports and delivering professional oral presentations. This means of acquiring engineering education is probably the closest approach to the reality graduates will find in actual companies, and therefore it provides an excellent training for their professional future. It reinforces those skills that are highly valued by industry within a global frame.

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BIOGRAPHICAL INFORMATION

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Samir Khoshaba is lecturer in Machine Design and Product Development and has been program director for mechanical engineering on bachelor level since 1997. He is also very active in the field of internationalization and student and teacher exchange program. He has also published some conference joint paper about teaching methods and pedagogy. The research area is about failures in gearboxes in lifting machineries.

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