INTEGRATING BUSINESS SKILLS IN ENGINEERING EDUCATION: ENHANCING LEARNING USING A CDIO APPROACH

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ABSTRACT

University degrees, such as engineering, that focus on professional competences are becoming increasingly popular in Sweden. However, there is still a need to not only include but to integrate different interdisciplinary skills in courses and education programs. This paper reports and analyzes a case study of the integration of business skills in two different courses on different study programs and levels. The results show that by shifting the actual foundation of a project course from technology to business development, a high level of engagement are achieved, among the students, to work with technology in a more realistic context. By integrating teaching of different professional skills alongside disciplinary knowledge and by putting disciplinary engineering courses into context, e.g. a business context, the students tend to work more systematically and rigorously both in conceiving, designing and implementing their technical projects. Hence, the situation becomes more similar to a real situation in the industry, where value driven development is a necessity. Additionally, by integrating teaching of such skills into the curriculum of several courses during a engineering program according to the CDIO Approach, a better understanding and a shift in the students' individual choices on project courses towards value driven development can be seen.

KEYWORDS

Integrated learning experience, Interdisciplinary courses, Standards: 1, 2, 3, 5, 7, 8, 9

INTRODUCTION

To study at the university has become an obvious choice for the young population in Sweden and to have a university degree is important regardless of future profession. The degrees awarded in Sweden today can be divided into general degrees (e.g. Bachelor's and Master's degrees) and professional degrees (e.g. medical, engineer and psychologist). Statistics show that, in Sweden, students applying for higher education programs clearly tend to choose study programs that lead to degrees closely connected to certain professions, such as an becoming an engineer (UHR, 2014). In general, students within engineering can either choose to study towards a Bachelor of Science Degree in Engineering (3 years) or a Master of Science Degree in Engineering (5 years), which both are, what in Sweden is denoted as, professional degrees. Since these study programs have such close connection to the profession it is important not only to discuss the knowledge that the students acquire in the field of study, but all skills needed by the students to cope with their future profession. Schwieler (2007) mentions skills such as social competencies, intercultural competencies, entrepreneurial competencies and managing competencies as important for engineers. Furthermore, these multifaceted skills are, in general, desired by the industry (Mechefske, Wyss, Surgenor & Kubrick, 2005).

Hence, the education should not only provide knowledge within the specific field of study but also make the students “prepared to live and work as global citizens, understand how engineers contribute to society. They must develop a basic understanding of business processes” (Vest, 2007, p. xiii). Many engineering programs are founded in the ideas suggested by CDIO (Crawley, Malmqvist, Ostlund & Brodeur, 2007), which is the case of the education programs at Umeå University. CDIO is an organization that has the aim to help bridge the gap that currently exists between engineering education and the business community's view on engineering skills needed by the students. Thus, the students should be able to *Conceive*, *Design*, *Implement* and *Operate* in their role as an engineer, which means that knowledge and skills in all parts of a product's life cycle are of great importance. This involves, for example, identifying needs, planning the development process, develop, production, maintenance and marketing products. Hence, the idea is more explicitly to prepare students for a future career in the industry without changing the academic demands placed on students. The CDIO model provides a broad base for the generic skills that can be expected by both current and future engineers.

Studying and learning are in many ways active processes. Today, project-based learning in a very common way to assimilate some of the skills needed as a professional engineer, and not only disciplinary knowledge. Using this type of learning process is also something that has been deemed appropriate and successful in engineering education (De Graaff & Kolmos, 2003; Mills & Treagust, 2003). Furthermore, basing the teaching on projects also aims to increase the students’ motivation to take responsibility of their own learning process (Turner & Paris, 1995). Therefore it is important for teachers in higher education to move some of the focus from the disciplinary subject area and link the students' projects to a social and business context and relevance (Cardozo et al., 2002). Although different projects on different courses connected to an education program have different objectives, there is often a freedom in some of the choices made by both students and teachers linked to projects in today's engineering education. This paper reports and analyzes a case study (e.g. Stake, 2005; Yin, 1994) of the integration of business skills in engineering courses to put project courses in a more realistic context and further support the design-build test approach.

METHOD AND STUDY DESIGN

This case study analyses process and results from two different courses on different levels and study programs at the Department of Applied Physics and Electronics at Umeå University, in which students' knowledge of business development and business thinking are integrated with a technical development project. These courses illustrated in this article seek to respond to the need to give students skills within the Extended CDIO Syllabus 2.0 regarding integration of business skills in engineering education. Thus, the purpose of this article is to discuss and raise interest in issues related to the role of the engineer as part of the development of society. The courses studied in this paper are *Engineering in a business context* and *Service design and business models in an engineering context* (Table 1).

Table 1. The two interdisciplinary courses included in this case study.

Course	Study program	Level	Study year
Engineering in a business context (15 ECTS, spring, 100%)	Bachelor of Science Program in Electronic and Computer Engineering (3 year education program)	Basic	Third year
Service design and business models in an engineering context (7.5 ECTS, fall, 25%)	Master of Science Program in Interaction Technology and Design (5 year education program)	Advanced	Fifth or fourth year

The courses studied in this research (Table 1) have learning outcomes that relate to both disciplinary and interdisciplinary knowledge. The interdisciplinary learning outcomes are integrated into the curriculums of the courses and focus on e.g. business development and project management. The learning outcomes related to interdisciplinary knowledge are presented in Table 2.

Table 2. Learning outcomes related to interdisciplinary knowledge.

Engineering in a business context	**Service design and business models in an engineering context**
Discuss the concepts of entrepreneurship, business model and business plan.	Apply appropriate techniques for creative product and service development.
Describe the basic laws and regulations relating to start-ups and small businesses.	Specify a product or service and develop a prototype.
Explain basic principles regarding financial reporting.	Establish and follow a project plan for a defined development project.
Evaluate and assess the quality of a finished product on the basis of functionality, technical level and compliance to the specification.	Apply engineering and business knowledge during conceiving and designing a product or a service based on a business idea.
Evaluate, design and present business plans and identify the strengths and weaknesses of these.	Prepare and present a business plan, financing strategy and marketing plan for the project.
Analyze the learning process in terms of creativity, initiative and entrepreneurship.	Formulate a career plan and a plan to build a personal network.
	Evaluate and assess the quality of a finished product.
	Evaluate the project from a personal career perspective.

The data collection for this study (Table 3) has been longitudinal during 2012 to 2016 and was conducted using ordinary anonymous course evaluations (at the end of each course) and anonymous online student surveys (1-2 per course) (Fowler, 2014) spread out during the course as well as group interviews with students (1-2 per course). The group interviews gave qualitative and exploratory insight into the results from the evaluations and surveys. All participation, in any of these data collection sessions, have been voluntarily by the students and to minimize the bias in the surveys, the students were not informed about the use of the data in research beforehand (Aleamoni & Hexner, 1980).

Table 3. List of number of courses included in the data collection used in this case study.

Course	**Course evaluations**	**Student survey**	**Group interviews**
Engineering in a business context	4 (2013-2016)	2 (2015-2016)	1 (2015)
Service design and business models in an engineering context	3 (2013-2015)		4 (2012-2016)

Using case study methodology has limitations in generalization. However, this paper does not aim towards generalization but rather to give insight into the integration of business skills in engineering programs in line with the CDIO principles. Furthermore, Stake (2005, p. 460) states that “the purpose of a case report is not to represent the world, but to represent the case”. The use of a case study, in this case, is suitable since the project is a “unit of human activity embedded in the real world; which can only be studied or understood in context; which exists in the here and now; that emerges in with its context so that precise boundaries are difficult to draw” (Gillham, 2000, p. 1).

RESULTS

Even though a definition of engineering by the American Engineers' Council for Professional Development (ECPD) was stated in 1947 as "the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property", this definition still have great impact on engineers and engineering in the 21st Century. Hence, to work and have a career in engineering, acquiring a broad range of generic skills is becoming increasingly important for students (Mechefske, Wyss, Surgenor & Kubrick, 2005; Schwieler, 2007). CDIO is an international initiative that provides a framework for providing engineering skills in engineering education. The fundamentals of CDIO is to better prepare students for future work as engineers in the industry by providing necessary skills not only within the area of focus, but everything needed for life-cycle thinking of products and services. According to Crawley, Malmqvist, Ostlund & Brodeur (2007, p. 1), "the CDIO approach builds on stakeholder input to identify the learning needs of the students in a program, and construct a sequence of integrated learning experiences to meet those needs". Hence, the focus is on the stages - *Conceive*, *Design*, *Implement* and *Operate*. The courses analyzed in this paper aim towards providing results that connect to the CDIO standards regarding Context (Standard 1), Learning outcomes (Standard 2), Integrated curriculum (Standard 3), Design-implement experiences (Standard 5), Integrated Learning experiences (Standard 7), Active learning (Standard 8) and Enhancement of Faculty Competence (Standard 9).

Interdisciplinary courses in engineering education

Due to its ability to support and address both disciplinary skills and generic skills, project-based learning has become increasingly common in engineering education (Mills & Treagust, 2003). Hence, by working with projects, students' inner motivation, need and will to increase their learning in adjacent areas can increase. Furthermore, great care should be taken into setting up project teams and choosing projects since students tend to have a better learning experience connected to teamwork from good experiences than from bad ones (Bacon, Stewart & Silver, 1999). Since the project ideas on the courses in this paper are self-chosen by the students, it has proven to be more successful to have self-selected project teams due to the need of different competences in the group. These teams also provide a better real-world experience and increase the value of the teamwork (Chapman, Meuter, Toy & Wright, 2006) and, thus, build collaborative learning (cf. Elmgren & Henriksson, 2010; Turner & Paris, 1995). Similar projects have been performed in e.g. project management (e.g. Mejtoft & Berglund, 2015). The results of this paper are deeply funded in the principles of CDIO (Crawley, Malmqvist, Ostlund & Brodeur, 2007) and project-based learning.

Traditionally projects on courses within engineering have a linear structure involving creating concept, development (i.e. design and build) and presentation (or launch) of the product (Figure 1). This structure is well founded in the ideas of traditional project management and teaches the students how to work with available recourses within certain time constraints.

Figure 1. Structure of traditional projects on engineering courses.

Even though not always the case, this traditional structure further supports the thoughts of design-build-test as described by e.g. Malmqvist, Young, Hallström & Kuttenkeuler (2004). However, the idea of integration according to the CDIO Syllabus 2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) can be interpreted as to both increase the "need" that the students feel to prototype in their development and furthermore integrate the product development in a business development process (Figure 2). Hence, such approach more clearly supports the design-build-test concept, since the business development process demands a connection to, and, hence, proof for, a customer centric design method. The students comment on the idea of a business focus on their courses as: "It's important to think about how customers will react to our product and also what the actual value of a product is" and "It's basically all about money, so it feels like it is beneficial with insight into a business thinking when starting to work [as an engineer]".

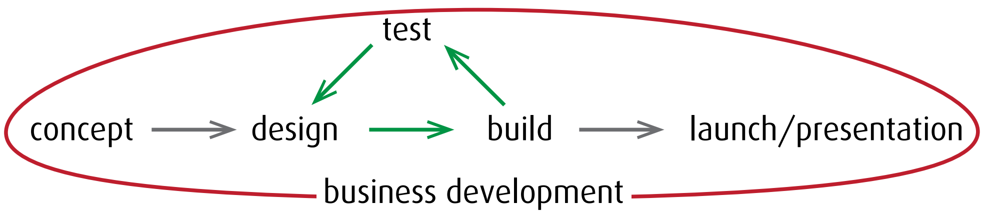

Figure 2. Structure and conceptual idea of projects when integrating business skills in engineering courses.

The results from this research show that introducing interdisciplinary courses that focus on business development in engineering education changes the students' view on the development process from a narrow technical angle to a broad holistic engineering perspective. Hence, by dressing the product (or service) development process in a business costume, a context is clearly created for the students, which gives them the opportunity to focus on "the creation and operation of the goods and services that will deliver value" (Crawley, Malmqvist, Lucas & Brodeur, 2011).

Focusing students' choices by integration

Even though large parts of business development are covered within theoretical parts through lectures and workshops, the students must add to the content in terms of disciplinary knowledge to be able to successfully complete the project work (Ying, Yan & Tong, 2010). This is done both through supervision of the projects and self-studies by the students. By changing the idea of a disciplinary course from a traditional structure (Figure 1) where all attention is on the disciplinary knowledge to a business oriented focus, the students' individual choices for the project get focused on situations, context and, foremost, actual value. Although the two courses studied have their real focus on technology and disciplinary engineering skills, the idea of presenting the courses as business oriented makes the students chose more carefully regarding *how* and *why* certain activities are performed.

There are great differences in which type of input that is needed whether a project in derived from a value driven perspective or a technologically driven perspective (Figure 3). However, the actual disciplinary activities performed are pretty much same or similar based on the input. Hence, it is possible to argue that even though creating a more realistic scenario with interdisciplinary skills integrated into the course, the thoughts on disciplinary knowledge are still intact but set in a context.

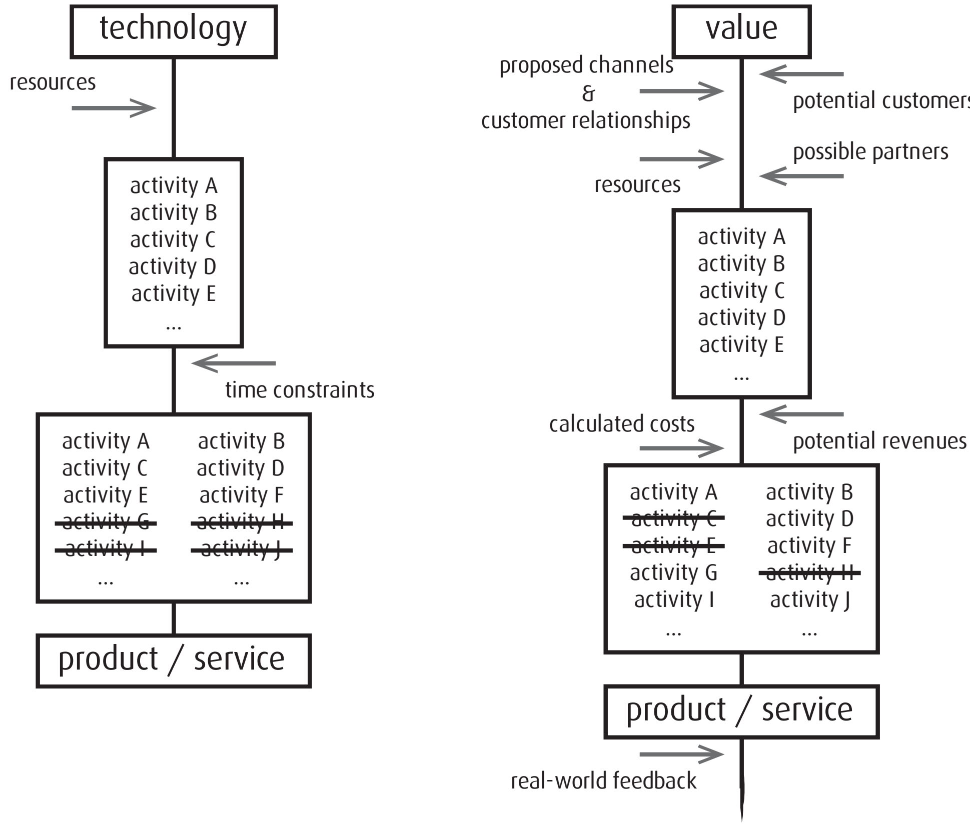

Figure 3. Difference in input and process depending on a technology driven or a value driven focus of the project.

The major difference in achievement by integrating business development in traditional project-based courses is that activities performed in the technical project will have to be structured and ranked depending on when in time they can be performed (based on when e.g. input from users can be collected) and all activities that are set at the beginning of the project will probably not be performed due to the actual need and what the users are potentially willing to pay for (Figure 3). Students express this as the course “gives a clearer picture of how the technology is supposed to be applied and other aspects such as usability, cost, design etc. must be taken into account, not just to merely make the technology work” and “it is important to think about how other people experience products and how important the perceived value of a product is”. Furthermore there are both positive aspects on these courses as well as problematic areas to deal with. The greatest benefits concern the gradually change in thinking that students gain through *a user-centric focus on development*: “I have become better to understand how others think, to create the best value proposition you have to put yourself in another person’s mind”, *a development in business thinking*: “I have become better to connect what I do to profitability, that what we develop should be economically viable”, as well as the opportunity to *nurture entrepreneurial behavior*: “I got much insight and knowledge of how it would be to start my own business”. The benefits of a broad approach to technology, which more tangibly connects to students’ future professional roles as developers, clearly are stressed by a majority of students in the courses.

Nevertheless, this also connects to the major disadvantage, stressed by the students, with a business development focus on courses. Since not all focus is on technology, changes in original plans have to be made and, sometimes, activities that the students wanted to perform might be discarded during the project, which has been mentioned by one of the students as the projects can be “obstructing in terms of the technological development”.

When discussion the course *Engineering in a business context* and the students at the Bachelor of Science Program in Electronic and Computer Engineering, it is possible to clearly distinguish a gradually increase in the understanding for business skills in engineering education during the 10 week course. Surveys during the first three weeks give indications that the primary reason for choosing this course was not the interdisciplinary approach, but the need for a project-based course to include in their degree (which is mandatory). Comments on why this particular course was chosen include: “Because I needed a project-based course and it sounded interesting with a more business oriented perspective” and “One project-based course is mandatory for graduation and out of the ones available, this was the most interesting one”. Even though spending most of the time working with a technical development project, at the end of the course the students more clearly list interdisciplinary skills both as important and as something they have been able to practice: “I have become better to connect what I do to profitability, that what we develop should be economically viable”, “I’ve been much better to argue for my standpoint” and “I got a better understanding for entrepreneurship and starting my own business”.

Understanding of the students’ professional role

The professional role of an engineer is much broader than just technology and sciences (e.g. Crawley, Malmqvist, Ostlund & Brodeur, 2007; Mechefske, Wyss, Surgenor & Kubrick, 2005). Generally, in education, there is a need to provide students with knowledge that bridge the gap between the knowledge of the different subject areas studied through the engineering program’s technical disciplinary courses. This knowledge is strongly related to the professional role of the engineer and the need to synthesize knowledge into a way of thinking about products and services. This kind of knowledge can be e.g. project management, sustainability and business development. The courses described in this paper focus to meet certain part in the CDIO Syllabus 2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) such as *Analytical reasoning and problem solving*, *Experimentation, investigation and knowledge discovery*, *System thinking*, *Attitudes, thoughts and learning* and *Ethics, equity and other responsibilities* in Personal and professional skills and attributes (CDIO Syllabus 2.0: 2) and *Teamwork* and *Communication* in Interpersonal skills (CDIO Syllabus 2.0: 3).

Touching upon the students’ motivation and to use external motivation to increase the inner motivation, combining academic teaching environments with real-world experiences are of great importance (cf. Mejtoft, 2015). Additionally to the “ordinary” project presentation at the end of the course, the courses described in this paper end with the students delivering a two minute pitch of their idea and project in front of 3-4 persons with high business knowledge in the same set-up as the TV-show “Dragons’ Den”. After the pitch, the student are engaged in a Questions & Answers (Q&A) session of approximately 6-10 minutes with questions from the “dragons” that have arisen during the pitch. During the course *Service design and business models in an engineering context,* this is done in cooperation with the industry and an external consultancy firm and the dragons are highly skilled business and management consultants. During *Engineering in a business context* the final pitch is set up internally at the University, but with people with high knowledge and experience from business development and that are previously unknown to the students. This final examination, that is separated in time and place from the project presentation in class, puts great pressure on the students since they have to strategically plan their learning process to correspond to “complex phenomena of the world, including facts and their interrelations” (Svensson, 1997, p. 60), since they have no idea which type of questions and reactions they will get from the

“Dragons” during the Q&A session. All students that have taken part of the external Dragons’ Den feel that this is a positive experience that increases the motivation to present and prepare more thoroughly for the final presentation and examination. The students comment the final pitch as: “Very fun and educational. I’m glad they gave a lot of feedback and really seemed to be interested [in our work]”, “Super fun! An educational, good and nervous experience. Being nervous means that it’s something new and challenging” and “An exciting task that meant you had to show your muscles a little extra, which is a very good exercise”.

Teacher’s disciplinary and interdisciplinary knowledge

The external company that provide the expertise in business development during the “Dragon’ Den”, described above, is very satisfied with the students and rank the students’ knowledge in business thinking at the course as high and also emphasis the progression from year to year on the course. The region manager of the external consultancy firm (and one of the “dragons”) that take part of the examination of the course stated that the “awareness, among the students, about the importance of a business thinking has increased significantly from year to year, there is no question about that”. This is a result of further integration of business model thinking in several courses included in the Master of Science study program in Interaction Technology and Design. Currently business model thinking is included in the courses *Interaction Technology and Design (7.5 ECTS)* on the first year and *Product development in media technology using the design-build-test method (7.5 ECTS)* on the third year. Hence, by integrating small pieces of generic skills during several courses a better understanding for the interdisciplinary skills are achieved. This is, however, not done on the third year Bachelor of Science Program in Electronic and Computer Engineering, in which case comments from the students are more connected to that the overall focus has shifted from technology to business. Even though the same or similar activities are performed.

To be able to support Integrated Learning Experiences (Standard 7), and, thus, an Integrated Curriculum (Standard 3), the lecturers and supervisors knowledge is important. Even though it is possible to integrate business skills, as described in this paper, based on several supervisors and lecturers with different knowledge, this do not truly give a successful integrated learning experience. Hence, to truly integrate generic skills into engineering education increases the demand on lecturers and supervisors to have broader knowledge and understanding for context and interdisciplinary skills than just the disciplinary knowledge.

CONCLUSIONS

To prepare students to act in a dynamic and fast-paced business environment is one of the main goals for an education program. This includes both disciplinary and interdisciplinary knowledge that are needed for students to be able to work as professionals. One of the main problems with integrating interdisciplinary subjects and skills in today’s engineering education is a tight and already full curriculum. This paper illustrates how business skills can be integrated into the current curriculum by integration into disciplinary engineering courses. The results achieved during this project illustrate that by shifting the actual foundation of a project course from technology to business development a high level of student engagement to work with technology in a more realistic context can be achieved.

By integrating the teaching of different professional skills and by putting disciplinary engineering courses into context, e.g. a business context, the students work more systematically and rigorously both in conceiving, designing and implementing the results of their technical projects. Hence, the situation becomes more similar to a real situation in the industry. Moreover, by integrating the focus and teaching of such skills into the curriculum of several courses during an engineering program according to the CDIO approach, a better understanding and a shift in the students' individual choices on project courses towards value driven development can be seen. Forming cooperation with external partners to provide input into e.g. the final stage of the students' work, in this case a "Dragons' Den", increases the students' motivation to engage in the project work. However, the results from the study show that setting up a similar examination with internal staff that the students are not familiar with gives similar results.

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