STUDENT LEARNING EXPERIENCES CONCERNING ENTERPRISE & SOCIETAL CONTEXT IN CDIO-BASED EDUCATION

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ABSTRACT

The CDIO Syllabus includes a section dealing with Enterprise, Societal and Environmental Context (Section 4) that was extended in 2011, which implies its growing importance. The goals and content of this section differ from those of the core engineering sections and include awareness of the impact of engineering on society and environment as well as management of people and resources. It may be challenging to teach and learn these topics within the timeframe of already dense educational programs. In this paper we present both the ways of incorporating this section into curricula and a survey of student learning experiences using engineering programs at Linköping University, Sweden, as the empirical setting. Our study covers five engineering programs: Applied Physics & Electrical Engineering; Computer Science and Engineering; Engineering Biology; Industrial Engineering & Management; and Mechanical Engineering. The results show that some of the programs incorporate Section 4 topics mainly through project courses where student teams work on specified assignments within their programs' focus area (such as software) while training their project management skills and gaining insights into business and societal context. Other programs, especially Industrial Engineering & Management, include several courses where Section 4 topics are learned through lectures, seminars, experiential learning and less extensive group assignments. The results from our survey of students' learning experiences show that students vary in their evaluation with regard to section 4 topics, with for example Mechanical Engineering students valuing their program higher than others when it comes to their learning about responsibilities of engineers to the society. Industrial Engineering & Management students on the other hand value their program higher than others concerning learning of topics such as business context. We also show that extra-curricular activities in the form of active engagement in students clubs at the university are beneficial for developing leadership abilities during engineering education.

KEYWORDS

CDIO Syllabus, Learning experience, Societal context, Soft skills

INTRODUCTION

It is an ambitious and indeed necessary endeavor to incorporate aspects such as societal context, management and leadership into engineering education. As early as 1955 the Grinter Report [3] suggested there is a need to include courses in humanities and social sciences in engineering education with the aim of developing soft skills and understanding the interplay between technological and social systems. This need is recognized by both CDIO syllabus [1-2]

as well as Accreditation Board for Engineering and Technology, ABET, criteria [4]. As several authors have noted, the engineer of tomorrow will most certainly be required to work in multidisciplinary environments; be familiar with non-technical subjects; and to have an understanding of ethical and professional responsibilities, as well as social and cultural skills [5-7]. This calls for an integration of topics from social science into engineering education.

In our experience, engineering students tend to consider courses in social science and management subjects such as organizational behavior and project management enjoyable and valuable for working life, but also difficult. The distinctive approach of social science requires "cognitive flexibility" [8] and new "habits of mind" [9] due to the focus on understanding and interpretation of human action and fewer possibilities for experimenting and predicting outcomes. Therefore, this paper focuses on how subjects such as societal context can be integrated within engineering education, using Linköping University as an empirical example. We will study the structure and organization of five engineering programs concentrating on this specific focus and analyze students' learning outcomes and experiences using survey method.

ENTERPRISE AND SOCIETAL CONTEXT IN ENGINEERING EDUCATION

The CDIO Syllabus version 2.0 consists of four sections with one whole section dedicated to enterprise and societal context [2]. Furthermore, this section was extended between the original syllabus and version 2.0, implying a growing importance of these issues in face of such factors as ongoing globalization and future engineering challenges [10], e.g. developing the provision of energy, water supply, and healthcare.

Following eight subsections constitute section 4 of the CDIO Syllabus version 2.0:

- External, societal and environmental context
- Enterprise and business context
- Conceiving, system engineering and management
- Designing
- Implementing
- Operating
- Leading engineering endeavors (extension added in v.2.0)
- Engineering entrepreneurship (extension added in v.2.0)

These themes listed above in turn include a multitude of varying topics in the detailed version of the syllabus, topics such as: contemporary political, social, legal and environmental issues and values; enterprise strategy; project management; logistics; and investor networks. It is obvious that integrating these topics into engineering education is valuable for the engineers of tomorrow and their employers as noted by authors such as Shuman et al [4] and Duderstadt [7].

Previous research suggests that although this are important topics there are also worries about crowding out other essential topics from the curricula, overburdening faculty, and increasing requirements on the students [11]. Learning of these topics also often calls for methods which can be less familiar to faculty, for example case studies [4] or project-based and problem-based learning [9, 12, 13]. Furthermore, it has been expressed that aspects such as awareness and values can be difficult and costly to evaluate and asses [4, 12].

Interesting possibilities for integration of engineering education and soft skill development include studying languages in conjunction with going abroad for an internship or developing project courses related to actual challenges from industrial settings [4]. Many universities are

currently providing their own versions of this type of learning experiences, examples include MIT's Ideas Competition [14], Purdue's Global Engineering Alliance for Research and Education; and Engineering Projects in Community Service [15-16] and University of Colorado at Boulder's First-Year Engineering Project [17]. Such initiatives are resource demanding and therefore are dependent on institutional support at high levels within the university hierarchy as well as engagement of many members of the faculty.

Extra-curricular activities during higher education can make an important contribution to the development of knowledge and skills related to leadership, entrepreneurship and organization. They have an important role to play in CDIO-based education as they offer possibilities to apply acquired skills and knowledge in a protected environment, test modes of thinking and acting, develop sense of responsibility as well as abilities such as negotiating and working together with peers towards common goals. A study by Tchibozo [18] of graduates in the UK identified a stylized student profile called "Leaders and Citizens" which signifies students engaged in student associations at leadership level or in citizenship activities related to public safety, environment and political organizations. These students were more likely to work in managerial positions and at large firms after graduation than other students while also having lower risk of unemployment. This implies that employers value these types of extra-curricular activities and consider them a positive influence on the student. Consequently, such activities should be considered alongside educational programs when assessing students' learning environment and learning experiences.

METHOD

Data for this study are derived from five engineering programs at Linköping University, Sweden: "Industrial Engineering & Management", "Mechanical Engineering", "Applied Physics & Electrical Engineering", "Computer Science and Engineering" and "Engineering Biology" programs. All engineering programs at Linköping University have been CDIO-based since 2006 which means that almost all currently enrolled engineering students have participated in CDIO-based education since the beginning of their studies. The five programs analyzed in this paper were selected due to a relatively large number of students and variation in focus between the programs.

Data for this study was collected using three different sources: official documents, the program chairmen and the students. First, the authors have analyzed the course composition of these five selected engineering programs using with regard to course aims and content during first three years of each program. Second, chairmen of the program boards for all selected programs with the exception of Mechanical Engineering have been interviewed in 2013. Open ended questions concerning the design of the programs and integration of Section 4 topics were used during the interviews. Finally, opinions and learning experiences of senior students from these programs have been studied using survey method during March 2013.

The survey includes items which measure the demographic information of the participants, how they evaluate their learning regarding different subjects (e.g. mathematics, technology, soft skills) within their program and their learning experiences related to enterprise, societal and environmental context. The students' experiences are recorded on a 5-point Likert scale anchored by "Strongly disagree" (1) to "Strongly agree" (5). The questions which are used in the survey were adapted from previous studies [19-20] and the section four of the CDIO Syllabus v2.0 [2]. Students from four of the five selected programs have been contacted through e-mail and asked to fill in an online version of the survey. Students from one of the programs have been asked to respond to the survey in printed version in connection with lectures at campus.

Table1. Profile of respondents

Student Profile	Percent of valid responses (number in brackets)
Type of Engineering Program	
Computer Science and Engineering	12.4 % (12)
Industrial Engineering & Management	37.1 % (36)
Mechanical Engineering	27.8 % (27)
Applied Physics & Electrical Engineering	22.7 % (22)
Being Aware of the CDIO concept	
Yes	34.0 % (32)
No	66.0 % (62)
Gender	
Female	11.5 % (11)
Male	88.5 % (85)
Being active in student clubs	
Yes	43.8 % (42)
No	56.3 % (54)

Overall there were 404 registered students at year four of these five programs. The survey has 104 respondents in total. Since there were only three responses from Engineering Biology program and four responses from other programs, these seven responses were eliminated from further analysis. As a result of this elimination, 97 responses were used in the analysis. General profile of the respondents can be seen in Table 1.

IMPLEMENTATION OF ENTERPRISE AND SOCIETAL CONTEXT AT LINKÖPING UNIVERSITY

The analysis of official course documents and interviews with the program chairmen show that each of the studied engineering programs has its own unique way to integrate section 4 topics of CDIO curriculum.

The program “Applied Physics & Electrical Engineering” combines applied physics with a knowledge base in electrical engineering and relies heavily on mathematics. Within the program there is also a focus on training of practical engineering skills such as lab skills. Section 4 topics are mostly dealt with during three so-called “Project courses” during year one, three and five of the program. During these courses students practice working on a project in groups, using project management tools, and communicating their results as well as attend lectures on subjects such as what it means to be an engineer. Entrepreneurship is dealt with in a module during the course in year five. Other courses in the program include aspects of section 4 topics, but these can be more or less visible and obvious to the students.

The program “Computer Science and Engineering” integrates knowledge of both hardware and software while also providing a solid base in mathematics. In the same vein as at the “Applied Physics & Electrical Engineering” program, CDIO section 4 topics are mostly offered through project courses. Furthermore, one of the chosen optional courses during the program should be within green IT/sustainability. There is one mandatory hardware project course and one mandatory software project course during year three. The projects students work on within the software project course are based on suggestions and needs from industrial partners, such as development of a weather app. These project courses include topics such as project management and business context. A third course which will stretch over the first three years of the program is currently under development. The idea is that the students during this course will be divided into groups of 10-12 students and have an opportunity to develop presentation

technique, discuss case studies, and share experiences with students attending both later and earlier years of the program.

The program “Engineering Biology” focuses on biotechnology and engineering for health care and medicine together with development of lab skills and experimental skills. Similarly to both of the above programs it offers section 4 topics in CDIO project courses. Here these are given during year one, year three and year four. The courses mainly consist of problem solving in groups with the problems getting progressively more difficult with each year. Students use project management tools during these courses and are given assignments such as writing reflection reports concerning the work dynamics of their project group. Furthermore, a mandatory course in entrepreneurship is offered during year five of the program. Topics such as ethical & environmental considerations are discussed in conjunction with lab work, and business context is integrated in field trips to firms offered in several courses.

The program “Industrial Engineering & Management” was designed from the start as an engineering program with a large portion of management and business courses. CDIO syllabus is used at this program more as a checklist and documenting tool for the program board to make sure that all important aspects are integrated within the program. Section 4 topics such as project management, business context, leadership and entrepreneurship are dealt with in several courses, both mandatory and optional.

The program “Mechanical Engineering” combines mathematics with subjects such as solid and fluid mechanics, structural engineering, production engineering and materials science. It offers a mandatory course in Accounting & Business during the first year and in Environmental Engineering during the second year. Additional section 4 topics such as leadership and project management are offered within elective courses. Project courses in the style of “Applied Physics & Electrical Engineering” program are available as elective courses.

In Table 1, Appendix A, all courses from the first three years of each program that include Section 4 topics are listed. Since years four and five of each program are more based on elective courses, they are not stated here.

Training leadership and organization skills during the years spent at Linköping University also occurs through extra-curricular student activities that are organized by student associations. Every engineering program has a corresponding student-driven club which is a student government body consisting of a core group of at least 30 students, and many other associated students. These clubs have responsibilities such as looking after the quality of their educational program; conveying internships at firms; organizing events such as career fairs, seminars and case-solving competitions as well as social activities such as pubs, dinners and excursions; and producing magazines and newsletters. Many engineering students participate in and help to organize club activities, and have an opportunity to apply and develop their knowledge and skills within leadership, entrepreneurship and organization. There also exist numerous other student associations within interest areas such as sports, computers, music, drama, film, politics, religion, and internationalization.

These extra-curricular activities and student associations are an important arena for development of the personal attitudes, values and social skills promoted in the CDIO Syllabus. There also seems to exist an awareness of the importance of this part of the educational experience at the level of university administration. In the Annual Report of Linköping University for 2011 it is expressed that cooperation between the university and the student associations is important and valuable for the quality of education [21].

ANALYSIS OF STUDENT LEARNING EXPERIENCES

Overall, the results of the student survey show differences in students' own evaluation of contribution of their program to their learning of section 4 topics (see table 2). For example, all students highly value their education when it comes to improving their ability to make priorities when working towards a deadline. However, social orientation (e.g. business or responsibilities of engineers to the society) is considered more difficult to learn at the engineering programs than soft skills like communication (with the exception of Industrial Engineering & Management students). Learning how to introduce new goods and services to the marketplace (subsection 4.7) is also generally considered more difficult than other surveyed topics. Mechanical Engineering students value their program higher than others when it comes to learning about responsibilities of engineers to the society, while Industrial Engineering & Management students value their program higher than others concerning topics such as development phases of a firm and leadership. Computer Science and Engineering students express that their education contributes fairly little to their understanding of the impact of engineering on environment, even though a mandatory course in sustainability is included in their program as shown previously.

Table 2. Results of one-way ANOVA test of students' learning experiences related to program

		Type of Program					
	Survey item	**D**	**I**	**M**	**Y**	**F value**	**Tukey test**
1	I am satisfied with my learning of soft skills (e.g. communication, teamwork) during this engineering program	3.1667	3.7714	2.8148	3.2727	4.769***	I>M
2	Social orientation (e.g. responsibility of engineers to the society, business etc.) is easy to learn at this engineering program	2.2500	3.8611	2.6667	2.5455	17.130***	I>D, I>M, I>Y
3	Soft skills (e.g. communication, teamwork) are easy to learn at this engineering program	2.8333	3.7500	3.1481	3.0000	4.222***	I>D, I>M, I>Y
4	My education increases my awareness of the responsibility of engineers (e.g. safety, reliability) to the society	3.2500	2.9722	3.7037	3.3636	2.501*	M>I
5	My education increases my understanding of the impact of engineering on environment (e.g. pollution; efficient use of resources)	2.1667	3.2222	3.4074	3.3182	4.523***	I>D, M>D, Y>D
6	My education increases my understanding of different phases of development of a firm (e.g. startup; growth; and maturity)	2.1667	4.2778	2.7037	2.5455	27.400***	I>D, I>M, I>Y
7	My education increases my ability to design new goods and services to meet customer needs	3.5000	3.2500	3.4074	3.3636	0.251	--
8	My education increases my ability to introduce new goods and services to the marketplace	2.8333	3.5556	2.8077	3.1818	2.932**	I>M
9	My education increases my ability to lead other people	2.6667	3.8056	2.4074	2.9091	15.288***	I>D, I>M, I>Y
10	My education increases my ability to prioritize when working towards a deadline	4.2500	4.0278	3.9630	4.3182	1.177	--

***p<0.01; **p<0.05;*p<0.10
Abbreviations: D= Computer Science & Engineering, I= Industrial Engineering & Management, M= Mechanical Engineering, Y= Applied Physics & Electrical Engineering

In table 3 we show that extra-curricular activities in the form of active engagement in running students clubs at the university are beneficial for developing leadership abilities during engineering education. As shown previously in table 1 approximately 44 percent of the responding students stated that they are involved in such extra-curricular activities.

Table 3. Results of one-way ANOVA test of leadership ability related to involvement in student club

	Being involved in running student club			
Survey item	**No**	**Yes**	**F value**	**Tukey test**
My extra-curricular activities at the university increase my ability to lead other people	2.6000	4.1190	45.404***	NA

***p<0.01; **p<0.05;*p<0.10

CONCLUSIONS

The aim of this study was to examine how engineering programs incorporate the newly expanded section 4 of CDIO Syllabus into their curricula which are already very dense, and to analyze students' learning experiences.

Our interviews with chairmen of program boards at Linköping University show that there are great efforts to incorporate section 4 of CDIO into overall curricula of the engineering programs with each program having its own way of integrating topics related to e.g. society, business, entrepreneurship and design process. Some programs offer project courses where several topics are included in the context of group assignments such as software development. Meanwhile, other programs offer dedicated courses within areas such as entrepreneurship and project management.

The survey results show that overall social orientation is considered more difficult to learn at engineering programs offered at Linköping University than soft skills like communication (except at the Industrial Engineering & Management program). Introduction of new goods and services to the marketplace is also on average considered more difficult to learn than other surveyed topics such as prioritizing when working towards a deadline.

It is observed that offering not only specific courses but also opportunities to develop abilities and skills such as leadership in practice during student-led extra-curricular activities can provide a beneficial learning environment to engineering students.

Considering the ever-growing importance of employability and a broad set of abilities and skills among our engineering graduates, we conclude that the area of inquiry treated in this paper is an important one. Experiences of teachers, students, and alumni regarding integration of topics such as business context, leadership, entrepreneurship and design process into the engineering curricula provides a rich and valuable source of knowledge for analyzing and developing our programs into the future.

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APPENDIX A

Table 4. Enterprise, Society and Environment Related Courses at the Selected Engineering Programs of Linköping University

	INDUSTRIAL ENGINEERING & MANAGEMENT		MECHANICAL ENGINEERING		APPLIED PHYSICS & ELEC. ENG.		COMPUTER SCIENCE & ENGINEERING		ENGINEERING BIOLOGY	
Name of the course	**Type**	**S.**	**Type**	**S.**	**Type**	**S**	**Type**	**S.**	**Type**	**S.**
More Effective Studies	Ex	2	Ex	2	Ex	***2***	***Ex***	2	Ex	2
Industrial Placement	Ex	4	-	-	El	***4***	***Ex***	2	El	3
Professionalism for Engineers	-	-	-	-	-	-	M	1	-	-
Visits to Industry	-	-	-	-	Ex	2/3	-	-	-	-
Industrial Economics	M	1	-	-	El	6	-	-	-	-
Industrial Economics & Organization	-	-	M	2	-	-	-	-	-	-
Industrial Management	M	2	El	6	-	-	-	-	-	-
Project Management	M	6	-	-	-	-	-	-	-	-
Production & Operations Management	M	5	El	6	-	-	-	-	-	
Production Engineering	-	-	M	4	-	-	-	-	-	-
Manufacturing Technology	El	5	-	-	-	-	-	-	-	-
Work Science	-	-	El	6	-	-	-	-	-	-
Quality Management & Eng.	-	-	El	6	-	-	-	-	-	-
Intellectual Property Rights	-	-	-	-	-	-	El	6	-	-
Basic Marketing	M	5	-	-	-	-	-	-	-	-
Resource Theory	El	5	-	-	-	-	-	-	-	-
Entrepreneurship and New Business Dev.	El	6	-	-	-	-	-	-	-	-
Civil and Commercial Law	El	6	-	-	-	-	-	-	-	-
Economic Analysis: Decision& Financial M.	M	4	-	-	-	-	-	-	-	-
Economic Analysis: Economic Theory	M	4	-	-	-	-	-	-	-	-
Environmental Engineering	El	5	M	3/5	-	-	-	-	-	-
Intercultural Communication	El	3	-	-	-	-	-	-	-	-
Communication & Presentation	-	-	El	6	-	-	-	-	-	-
Machine-Technology Project	-	-	El	6	-	-	-	-	-	-
Project with Microcontroller	-	-	El	6	-	-	-	-	-	-
System Biology, Modelling Project	El	6	-	-	-	-	M	6	M	6
Software Engineering Project	-	-	-	-	-	-	M	6	-	-
Project Course in Electronics	-	-	-	-	M	5	-	-	-	-
Mechanical Engineering - Project Course	-	-	El	6	-	-	-	-	-	-
Microcomputer, Project Laboratory	-	-	-	-	-	-	M	5	-	-
Engineering Project	-	-	-	-	M	1	-	-	M	2

Abbreviations: El = Elective, M= Mandatory, Ex = Extra course with credit, X = absence of similar course, S=Semester, Type = Type of the course