INTEGRATION OF GENERIC SKILLS IN ENGINEERING EDUCATION: INCREASED STUDENT ENGAGEMENT USING A CDIO APPROACH

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ABSTRACT

To be able to successfully pursue a future career within engineering, students need to acquire not only disciplinary knowledge but also generic skills to become professionals. The CDIO model provides a foundation of generic skills that can be expected by the students' future employers. This paper presents pros and cons when integrating generic skills in disciplinary projects and is based on surveys and interviews with students and teachers on two integrated courses, Project management and Interactivity in smart environments, on an integrated five-year Master of Science program at Umeå University.

The results show that integrating two courses to give disciplinary meaning to projects make the students maintain their motivation during the course in Project management. In addition, the integration of the courses led to more time for the students for the actual project work. Lastly, both students and teachers also had the possibility to provide a better formal project structure on the disciplinary course. However, the results also show that the confusion among the students increased due to different requirements in each course. Thus, a high level of communication and a holistic view among the involved teachers is desirable to improve the overall success in course integration.

KEYWORDS

Project management, Case-based, Project work, Standards: 1, 2, 3, 5, 8, 11

INTRODUCTION AND THEORETICAL FRAMEWORK

Engineering education with a close connection to future profession is important and popular in many parts of the world. To be qualified for a future career as an engineer in the 21 Century, not only the disciplinary skills needed for a certain line of work is important for building the necessary professional skills but also generic and inter-disciplinary skills (e.g. Mechefske, Wyss, Surgenor & Kubrick, 2005; Schwieler, 2007). Generic skills are defined as "those which are achievable, worthwhile and essential for all undergraduate students regardless of their course of study … they underpin education and provide a basis to support lifelong learning" (Wright, 1997, p. 51). The high demand of a wide variety of skills on graduated students also put a huge pressure on education programs and individual teachers to give the students a possibility to learn both a broad range and the right set of skills during their training (Mechefske, Wyss, Surgenor & Kubrick, 2005; Schwieler, 2007). To cope with this and educate future engineers, the CDIO model (Crawley, Malmqvist, Ostlund & Brodeur, 2007) provides a broad base for the generic skills that can be expected by both current and future engineers and with the right design and implementation, a wide range of the personal and interpersonal skills stated in the CDIO syllabus can be met.

Asking future employers of the engineering students and professionals within the discipline, project management skills and communication in foreign language (i.e. English) are always stated among those important generic skills necessary for the students to learn (e.g. Pant & Baroudi, 2008; Stevenson & Starkweather, 2010). This corresponds well to the second paragraph of the CDIO Syllabus 2.0 - Interpersonal skills: Teamwork and communication. Nevertheless, in engineering education, project-based learning in a common, and appropriate, way to integrate the skills needed as a professional engineer, both disciplinary knowledge and generic skills (De Graaff & Kolmos, 2003; Mills & Treagust, 2003). Motivation is important when achieving goals and can be defined as "the process whereby goal-directed activities are instigated and sustained" (Schunk, Meece & Pintrich, 2014, p. 5). To focus teaching and learning around projects may also increase the students' motivation regarding their own learning process (Turner & Paris, 1995). Furthermore, integration of generic skills in disciplinary courses might increase students' motivation and give disciplinary knowledge more realistic contexts (Mejtoft, 2016), which makes the relevance of the project's outcome important regarding e.g. a social and business context (Cardozo et al., 2002). Previous research has shown that having real-world projects deeply integrated in education and using inter-disciplinary skills in solving disciplinary problems both increase the students motivation and give the students a better focus on professional, value-based, problem solving (Mejtoft, 2015; 2016).

This case study illustrates and analyzes how setting up a touch-point between two courses in a project work can push the education further towards the ideas of CDIO. The paper seeks to present pros and cons when integrating generic skills in disciplinary projects and is based on surveys and interviews with students and teachers on two courses. Using project-based learning is something that has been deemed appropriate and successful in engineering education (De Graaff & Kolmos, 2003; Mills & Treagust, 2003).

METHOD AND STUDY DESIGN

The case described in this paper is based on the principles of CDIO (Crawley, Malmqvist, Ostlund & Brodeur, 2007) in relation to the teaching and learning of engineering students. The main idea behind the CDIO initiative is to present a framework for preparing engineering students for their professional role and by providing all necessary skills not only within the disciplinary area, but also generic skills. The generic skills are needed for working within development of products and service as well as for a life-cycle thinking. Crawley, Malmqvist, Ostlund & Brodeur (2007, p. 1), state that 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". The stakeholder input and real-life scenarios needed for a true CDIO approach to education have made the use of different types of project based learning increasingly common within engineering education (Mills & Treagust, 2003). This is mainly because of its ability to include both disciplinary and generic skills in a setting similar to the student's future professional role. The case illustrated in this article seeks to respond to the need to give students skills within the CDIO Syllabus 2.0 regarding Interpersonal skills: Teamwork and communication.

The paper is based on an action based research approach implementing changes in two courses on the Master of Science in Interaction Technology and Design study program at Umeå University. The courses are "Project management" (7.5 ECTS) at the department of Applied Physics and Electronics and the disciplinary course "Interactivity in smart

environments" (7.5 ECTS) at the Department of Computing Science. Both of these courses are project-based (Krajcik & Blumenfeld, 2006), meaning that theory are taught in parallel with a project teaching and testing students ability to apply their skills. The courses are given in parallel during late fall parallel on 50% study pace. The implementation is based on using the project on the course "Interactivity in smart environments" as the basis of the course "Project management". This was a modification compared to previous years when a "fake project" without disciplinary connection had been used on the Project management course. The pedagogical project of combining the two courses aims towards providing results and learning outcomes connected to the CDIO standard 1 (Context), Standard 2 (Learning outcomes), Standard 3 (Integrated curriculum), Standard 5 (Design-implement experiences), Standard 8 (Active learning) and Standard 11 (Learning assessment). The students involved are all studying the Interaction Technology and Design Study Program at Umeå University. This is a five-year integrated cross-disciplinary Master of Science study program in media technology, interaction technology and interaction design. The entire program is firmly rooted in the CDIO approach with courses covering the central and important aspects of all four parts of the CDIO Syllabus as well as the CDIO Standards. Therefore, in addition to basic and standard engineering courses, the program have courses covering areas like business strategy and value creation, prototyping, development and testing along with using and operating systems as well as project management.

This paper reports a case study (e.g. Stake, 2005; Yin, 1994) of changes made during fall 2016 by integrating and making a touch-point between two different courses on a five-year integrated Master of Science program at Umeå University, Sweden. Since the authors were part of the actual changes studies, the used research approach is action based, implementing changes to two courses and studying the effect on the students. The data collection for this study has been done during late fall 2016 and early spring 2017 and with students and teachers involved in the two courses affected of the changes made. Furthermore, surveys have been done with students not involved in the changes. Data have been collected as both anonymous surveys (Fowler, 2014) spread out during the course and by auscultations and group interviews (Fontana & Frey, 2005) during students' meetings in the course "Project management". 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).

This paper is based on a single case study design of a unique case (Yin, 1994) and this paper is written in line with the ideas of Stake (2005, p. 460), that states "the purpose of a case report is not to represent the world, but to represent the case". Hence, even though using a case study based methodology has certain limitations when it comes to generalization, it is a suitable method for documenting this project since this paper aims to give insights into the change of education in line with the CDIO principles.

RESULTS AND DISCUSSION

To successfully learn engineering, projects are an important part to acquire the knowledge necessary. The foundation of CDIO is based on visions for engineering education that closely connect to the need of teaching the students project management – e.g. "Rich with student design-build-test projects" and "Integrating learning of professional skills such as teamwork and communication" (CDIO, n.d.). To work according to the CDIO Standards, most of the engineering students at Umeå University study the course Project management which

is based on both theoretical assignments and a group project. The purpose of the group project is to give the students both experience from and letting the students take part of a project. Thus, the philosophy and aim is “learning project management by doing a project” to facilitate collaborative learning (cf. Turner & Paris, 1995).

Background and implementation

This pedagogical project started during spring 2014, when evaluations of the course Project management had, for a while, indicated that the students had little motivation to perform during the Project management course. Using students to evaluate the course longitudinal in cooperation with the Program director found that the main reason for the low motivation among students was the project part of course. Hence, the motivation during the course dropped when this part had to be performed. Furthermore, previous evaluations also indicated that the lack of meaning of the projects was one of the major factors that lowered the motivation during the course. Most of the projects the students had to implement were “fake” projects with no real meaning or significance to the students, e.g. to make a baking instruction video, and plan for a public movie night at the University or a ski trip to the Alps.

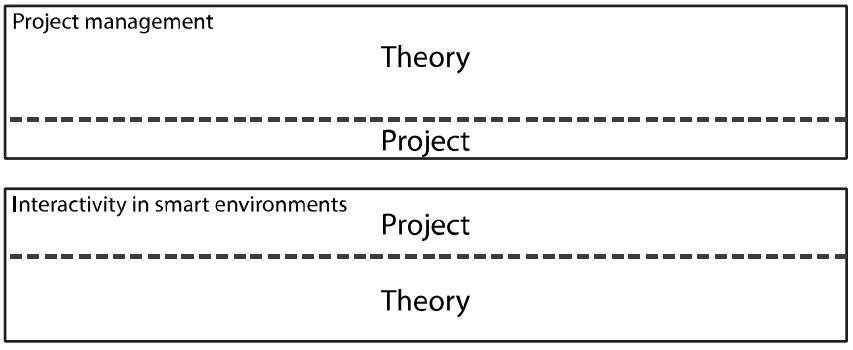

Figure 1. Traditional course structure: Two courses in parallel, no interaction.

The pedagogical project described in this paper was initiated to increase and maintain the motivation while studying Project management. The students at the Interaction Technology and Design study program are studying “Project management” in parallel with the disciplinary course “Interactivity in smart environments”. This course has a similar structure as Project management, but is disciplinary and the project is used to let the students apply their skills in a real situation. Thus, the students do carry out two projects on two different courses at the same time with no interaction – one with disciplinary meaning and no real project management structure and one general project with high level of structure in project management (Figure 1). In fall 2016 the two courses, described above, were combined and given a touch-point in having the same project for both courses (Figure 2). The overall aims were to (1) maintain the motivation among the project management students while carrying out the project, (2) providing a better formal project management structure to support the disciplinary course, and (3) give the students more time for disciplinary project work.

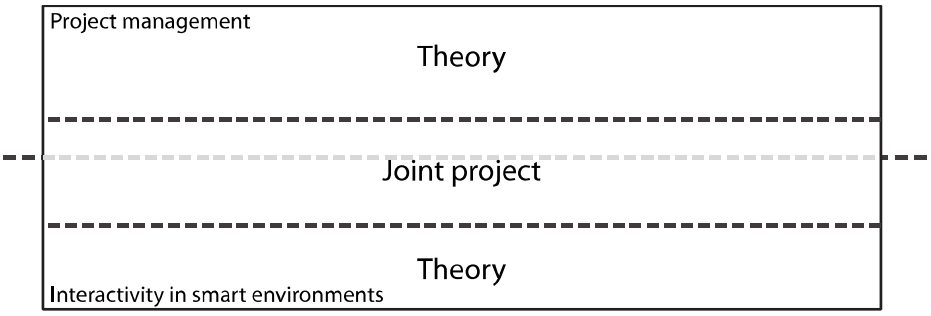

Figure 2. New course structure: Joint project creates touch point between two courses.

Both interviews and online questionnaires were used to assess the effects on the students from the new possibility to conduct a shared project, between the courses. The questionnaires were sent to the students at the start of the courses and at the end (after the final exam). The response rate of the first questionnaire was 66 % (19 out of 29) and the second questionnaire was answered by 79 % (23 out of 29).

Maintaining motivation

The first aim was to maintain the motivation on the project management course during the implementation of the project work. The results of the questions which were identical in the first and second questionnaire can be seen in Figure 3. The presented results are the mean values of answers on a Likert scale ranging from 1 to 5. It can be seen that the average value of the motivation during the course was equally high (3.7) both at the start and at the end of the course, i.e. no drop in motivation for the course Project management can be seen in Figure 3. However, a slight downward tendency during the progress of the course can be noticed in the motivation specifically connected to the interlinking of courses, (3.9 versus 3.3). Students commented this as: “Regarding the parts in project management, the motivation have been relatively high”, “Had high motivation in the beginning but became less with time” and “The motivation has gone up and down”. According to the students, this declining motivation could primarily be explained by unclear instructions and lack of feedback from the disciplinary course, which increased the students’ confusion about the goals. This will be further discussed later.

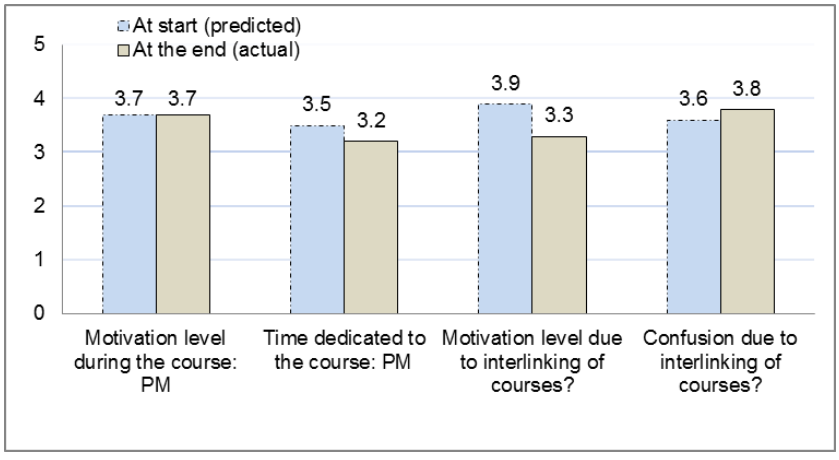

Figure 3. Summary of results from questionnaires sent to students studying the course Project Management.

Another reason for the slight decrease in motivation due to the combination of the two courses could have been that the students had very high expectations on the success of this course combination. This was measured in the questionnaire with the question: “Combining these two courses will make the course project management more interesting?” The result was an average agreement of 4.6. Such a high value is hard to improve. In that case, a more reasonable question becomes: How much of these high expectations will be fulfilled during the course? The overall motivational levels during the course shown in Figure 3 are taken to be that, to a large extent, this was fairly successful.

Better formal project structure

The second aim was to achieve a better formal project management structure to support the disciplinary course, i.e. Interactivity in smart environment. As described earlier, the main idea of the course Project management is to let the students produce all material necessary for managing a project while performing a project. Consequently, by integrating the two courses, the project on the course Interactivity in smart environments will have all necessary and formal project management structure. Hence, the goal of providing a better project management structure will be fulfilled as long as the students will continue and finish both courses, which was the case. However, there are other aspects of the results that are worth mentioning.

The results further show that by giving the students the task of setting up a formal project organization, makes specification, feedback and communication both in-between involved teachers and with students to become increasingly important. As mentioned above, unclear instructions and lack of feedback on the disciplinary course and communication between teachers on the two courses increased the confusion during the project work. This was commented by one student as: "Much time was spent on discussing what the demands of the course were and how we would solve them. The requirements [from the teachers] were very unclear and the discussions took up a lot of time". Thus, even though a formal project management structure was achieved, it is important that all involved teacher can support the process.

Spending more time on project work

The third goal of the project was to give the students more time for disciplinary project work. According to the syllabus of Interactivity in smart environments, the project part should account for 40% of the course (3 ECTS out of 7.5 ECTS). The results show that the student groups involved in this project have, on average, spent 105 h/student on project work (according to the self-evaluation of their project plans). Assuming that the students are working full time, equal to 40h/week (200h/7.5 ECTS), the average time spent on project work is 53%. However, experience show that most students do not spend full time studying, even though this is assumed here, making this figure probably a bit higher in reality.

Measuring the same results on the Project management course, a reference group was used that followed the old syllabus performing a “fake” project (as described above). In this case the results also show a noticeable difference in the time spent on the project work. The students involved in the pedagogical project spent, on average, 105 h/student and the students in the control group spent 43.5h. Thus, the results show that combining the two courses increased the time the students could, and was willing to, spend on working with the project.

Motivation and theoretical results

The Project management course ends with a written examination focused on theoretical parts of project management. Analyzing the score from the written examination between students conducting the disciplinary project versus those conducting a non-disciplinary project, it is possible to notice a significant difference in mean score (Table 1) between students with similar background within ICT/CS education (27.8 vs 22.2). However, performing an analysis of the results from three previous years (2012, 2014 and 2015) when all students performed a non-disciplinary project, the same difference can be noticed between the different student groups. Hence, the results illustrated earlier, i.e. that a disciplinary project make the students maintain their motivation during the project (and the course), do not reflect upon the results on the written theoretical examination.

Table 1. Average score on written examination 2016.

	MSc Interaction Technology and Design	*MSc Computing Science*	*All other students*
Project type	Disciplinary project	Non-disciplinary project	Non-disciplinary project
*Number of students**	31	15	48
Mean score on written exam	27.8	22.2	21.2

** All students turning in blank or scoring 0 points have been excluded*

Increased student engagement based on CDIO

In general, the students were happy with the changes and it is shown that not only was the aims of the pedagogical project met, but also made the students address the core of CDIO approach. The students made comments such as: “To get a grasp of working with a multi-disciplinary cooperation and to get insights from different perspectives” and “It was fun that the project, which was carried out during this course, was a ‘real’ project with an external client, etc. I also believe that we had more time compared to performing two different projects in parallel”.

Furthermore, the results show that this pedagogical project has given positive results based on several of the CDIO Standards regarding the curriculum. CDIO standard 1 (Context) by giving the students possibility to conceive, design and implement during a project based on a context closer to their future profession, Standard 2 (Learning outcomes) by letting the students gain personal and interpersonal skills in relation to disciplinary knowledge, which is important for maintaining high motivation, Standard 3 (Integrated curriculum) by integrating a course providing personal and interpersonal skills with a disciplinary course to create a more “real” scenario, Standard 5 (Design-implement experiences) by giving the students possibility to design and implement during a project on advanced level, Standard 8 (Active learning) by students in a structured manner, based on project management principles, applying knowledge, analyzing and evaluating ideas and Standard 11 (Learning assessment) by students presenting results and skills both in group and individually.

One question that arises when analyzing the data is: To what extent do the student’s initial ambition and motivation influences the results? It is far stretched to say that the results for this investigation are generalizable, but there are indications that the motivation could be maintained by integrating the same project work in the two courses. It is, however, important to have an overall education program structure that continuously support student’s motivation

to take responsibility of their learning process. In addition, to give the students opportunities to integrate different skills needed for their future profession in disciplinary courses cannot be stressed enough, i.e. a more Integrated Curriculum (CDIO Standard 3). The results further indicate that just integrating skills during a few courses might give the students a feeling of confusion regarding the courses and project work, since this is not the norm. Putting the norm among the students that working with integrated projects connected to all parts of CDIO more often would, not only, prepare the students for their future career, but also raise the bar of the responsibility among the students for their learning. However, challenges arise when students pose higher demands on teachers to give timely feedback, provide knowledge and to have a holistic view of the project and integration among different courses.

CONCLUSIONS

The students had very high expectations on the success of combining the two courses and performing one shared project. The results from this pedagogical project show that the end result was successful both in terms of student satisfaction and also based on several of the CDIO Standards regarding the curriculum. Furthermore, the students maintained their motivation during the project work which historically had been a major problem with the Project management course. The students also could, and were willing to, spend more time on implementing the project. In addition, the formal structure of the disciplinary course was strengthen by implementing all formal project documentation.

Nevertheless, even though it seems like the students in general would like to keep this new structure of combining Project management with a disciplinary course, there were some associated drawbacks. The most noticeable problem was the confusion that developed among the students due to different requirements when two courses from two different department at the University were combined. Thus, for a successful continuation of this structure, a high level of communication and a holistic view among all teachers involved are desirable. Additionally, an overall structure that would continuously support, on several courses, the students' motivation to take responsibility of their learning process and give the students' opportunities to integrate different skills needed for their future profession is important. This would be possible to achieve with a more integrated curriculum on a study program level and may increase the success of integration between individual courses.

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