ENGINEERING AND OCCUPATIONAL THERAPIST STUDENTS IN DESIGN PROJECTS – CROSS-DISCIPLINARY MEETINGS

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ABSTRACT

Engineering students need to develop their abilities to communicate their ideas in cross-disciplinary situations. This paper presents the results of a longitudinal inter professional teaching activity involving collaboration between engineering and occupation therapist students in design projects at Linköping University, Sweden. The objective of this paper is to share and reflect on experiences of integrative teaching activity in a course in Product Ergonomics for engineering students in Design and Product Development. The paper is based on the engineering students' evaluations, interviews with teachers and the authors' own experiences of the teaching activity. The course consists of two parts, a theoretical part and an applied product development project. During the project, the students are trained to develop and present credible product concepts. In this phase, the engineering students meet with occupational therapist students at the Faculty of Health Sciences. The engineering students then learn and benefit from the other students' knowledge fields. They also train to communicate with other disciplines and are able to demonstrate their engineering skills, the latter when they reflect on in parallel ongoing design projects undertaken by the occupational therapist students. As a result of the meeting with the occupational therapist students many engineering students modify the direction of their design project. The engineering students also receive good advice on how to approach and learn about the user of the product that is to be designed. Some issues that need to be taken into account for the integrative teaching activity include the timing for the meetings between the student groups, number of meetings and how to prepare the students.

KEYWORDS

Product development, Ergonomics, Communication, Collaboration, Standards: 2, 3

INTRODUCTION

Product development is characterized by integration, both technical and organizational, where the latter refers to integrating different organizational functions in the development process (Johannesson and Persson, 2004). These functions in are for instance marketing, construction, sales, and production. Studies show that collaboration between people with different backgrounds is essential and to develop high-quality products (Wind and Mahajan, 1997). Research on new product development (NPD) also highlight the importance of developing co-development alliances on an organizational level (Emden et al, 2006) and cross-functional teams within and company sites are common (Ulrich and Eppinger, 2012; Andreasen and Hein, 1987). It is therefore important for engineering students to develop their abilities to communicate their ideas in across disciplines situations. This implies training the engineering students to communicate their own ideas to groups outside the university, but also encouraging them to learn the need and benefits of collaborating with other groups. In future work, the interpersonal skills may even outweigh a technical curriculum in some cases (Bhavnani and Aldridge, 2000).

In research, collaboration across disciplines has been encouraged since at least the second World War (Williams, 1946). The experiences from these undertakings have been both positive and negative. In order to work efficiently, a general conclusion is the need to manage resources and create an understanding for each other's disciplines (Blackwell, 1955; Stemper, 1991). Costs increase due to a need for project coordination, administration, and travels. Researchers from the different fields also need to harmonize epistemologies, create rules for cooperation as well as decide methods for research and research goals. Stemper (1991) further puts forward that working across disciplines in both research and teaching can be conducted in five ways; *intra-disciplinary, cross-disciplinary, multidisciplinary, interdisciplinary,* and *transdisciplinary*.

Stemper (ibid) states that *intra-disciplinary* is the easiest form of collaboration and stands for when teachers and researchers are working within one discipline, for instance teaching subthemes, such as math and thermodynamics, to mechanical engineering students. *Cross-disciplinary* stands for working between two disciplines with the same theme, as in this study where engineering and occupational therapist students work with developing products from an ergonomic perspective. *Multidisciplinary* is a higher level of cross-disciplinary collaboration, which aims at working with several disciplines in one research project or study program to provide different perspectives on the same subject. In *interdisciplinary* cooperation, the partial contributions of the different disciplines are integrated to create a coherent whole or a general concept. Finally, the highest level in Stemper's (ibid) ways of collaboration is *transdisciplinary* collaboration, which is described as *"the unity of intellectual frameworks beyond the disciplinary perspectives"*.

This paper presents the results of a longitudinal teaching activity involving collaboration between engineering and occupational therapist students in design projects at Linköping University, Sweden. The objective of the paper is to share and reflect on the experiences of the cross-disciplinary teaching activity in a course in Product Ergonomics for engineering students in Design and Product Development (DPD). The reported experiences are from a six-credit course in Product Ergonomics. It is a compulsory course for third year students in the engineering program Design and Product Development.

The DPD program has been developed to meet demands on future engineers to be able to solve technical and functional problems as well as usability issues, and it includes classical engineering subjects such as Mathematics and Engineering as well as e.g. Ergonomics, Industrial Design and Interaction Design. The goal is to educate creative product development engineers who have a human centered approach (ISO-standard, 2010) and an understanding of aesthetic values when developing new products and services.

In the subsequent chapter, the method for this paper is described, followed by a description on how the collaboration between mechanical engineering and occupational therapy was developed. The course Product Ergonomics, within which the collaboration takes place for the engineering students, is then described. This is followed by experiences of the collaboration from the students' and teachers' view respectively. The paper ends with a discussion about experiences, advantages and challenges, and a final conclusion.

METHOD

Data for this paper were collected through questionnaires in which the engineering students' evaluated the cross-disciplinary meetings during four years, see Table 1. The questionnaire topics included the perceived importance of the meetings, learning by the engineering students, and improvement suggestions.

Table 1. Evaluation questionnaires to engineering students

Year	No of respondents
2013	58
2014	43
2015	56
2016	54

Data were also collected through semi-structured interviews with three teachers (two from engineering and one from occupational therapy) who initiated the collaboration between the engineering and the occupational therapist students. Interview topics were the background to the collaboration, experienced positive outcome and challenges.

The paper is also based on the authors' own experiences of being teachers and/or examiners during five years in the Product Ergonomics course.

DEVELOPMENT OF COLLABORATION BETWEEN MECHANICAL ENGINEERING AND OCCUPATIONAL THERAPY

In spring 2003, the Mechanical Engineering board of directors at Linköping University, Sweden, made a decision that a new five-credit project course named Product Design should be developed and start during the fall in the same year. Two teachers at the division of Machine Design were assigned to develop the course, and as a theme they selected "Tools for Veterans". The idea behind this project theme was to develop aids and tools for elderly people with disabilities. Due to the chosen theme, a contact was initiated with the Occupational Therapist program (OT) at the faculty of Health Sciences at Linköping University. Occupational therapist expertise is to adapt environments to people with disabilities thereby facilitating for them to work and have meaningful daily activities. The contact at the OT program was very positive and this developed into a course collaboration where engineering and occupational therapist students cooperated in product development projects and teachers giving lectures to respective student group. The aim of this integrative teaching activity was that the students should (Kjellberg et al, 2006):

- Gain insight and knowledge in the area of design and human factors
- Identify and analyze problems close to the reality from user's perspective
- Achieve the ability to develop alternative and creative design solutions starting from a problem formulation
- Develop a reflective attitude towards "design for all"
- Be able to evaluate different design qualities

The collaboration was designed in such a way that both faculties had their own courses and the two student groups had joint projects. This setup made it possible to avoid administrative difficulties such as student registration and course funding.

The mechanical engineering students contributed with their knowledge in mechanical design and the occupational therapists with their knowledge in human needs focusing on elderly people. The course was very popular from the start, and approximately 50 to 60 engineering students applied for the Product Design course and 20 to 30 OT students chose OT´s product development course. The project groups where selected so that two thirds were engineering students and the rest OT students. In its final design, the course curriculum focused on product development, basic industrial design skills and basic physical ergonomics.

The collaboration is still ongoing but has developed over the years. The first development occurred after two years when the OT program moved from campus Linköping to campus Norrköping, which is situated 46 kilometers away. The OT program also went through an extensive curriculum change toward a Problem Based Learning (PBL) educational philosophy. The introduction of PBL changed the OT students' schedule from having several courses in parallel to having an integrated course that extended over the full semester. The machine engineering students' curriculum remained the same. These two major changes made it more difficult to synchronize course schedules. The distance between the two campuses, 35 minutes by campus bus, made it more difficult for the OT and engineering students to meet up in their project groups and plan project tasks. The changes lead to a more scheduled collaboration where the OT students initiated the projects by giving the engineer students a user problem and then only participated in evaluating concepts and the final results.

The second major change occurred in 2011 when the Product Design course was cancelled due to curriculum changes for the engineering students. Both the OT teachers and the engineering teachers wanted to maintain the collaboration between the faculties. A decision was therefore made to move the collaboration to a compulsory Product Ergonomics course at a newly formed Design and Product Development program (DPD), which had started in 2008. The DPD program is an engineering program but has an industrial design and human-centered focus in the curriculum. New teachers from the Product Ergonomics course were involved in the collaboration, which was slightly changed again as the course content in for both student groups had changed. The DPD students now had to investigate user needs as a task in the Product Ergonomic course, while at the same time OT teachers had initiated a product development task in the separate course for the OT students, named Work Therapy in a Surrounding World Perspective. In the prior course, Product Design, the knowledge polarization had also been greater between the different student groups, thus rendering more distinct and clearer project roles. Mechanical engineering students focused more on the technical part of the project and the OT students on human needs. This second change influenced the collaboration into being more structured and distant. Students from the different programs got a consultant role to give feedback on each other's projects.

THE COURSE PRODUCT ERGONOMICS WITHIN DESIGN ENGINEERING

The six-credit course is designed to introduce the field of ergonomics and design and provides a basic ability to evaluate the applicability of ergonomics design as a methodology. It runs during the full autumn semester, and it consists of two parts: a theoretical part and an applied product development project. The learning outcomes of the course are related to several CDIO standards, of which the last is highlighted in this paper. After the course, the students should be able to:

- use some ergonomics theories and principles in product development (CDIO 1.1, 1.3, 2, and 4)
- use some qualitative and quantitative methods to understand the user's needs and requirements (CDIO 1.3, 2.1, and 4)
- assess and evaluate the consequences of ergonomics in products (CDIO 2 and 4)
- analyze and examine the role of ergonomics by discussing and evaluating different products and product development questions (CDIO 1, 2.1, 4.1, and 4.2)
- communicate with other disciplines, acting professionally as engineer in a multidisciplinary context and presenting product concepts in a credible way (CDIO 2.5 and 3.1)

During the theoretical part, the students learn concepts, models, and methods used in Ergonomics. Ergonomics is a multidisciplinary field (Wilson, 2000, 2014), and the course is therefore divided into weekly themes, see Table 2. Each theme is addressed in lectures, group assignments, and seminars.

Table 2. Themes within Ergonomics in the course

Theme	Content
Anthropometry	The anthropometry theme focuses on strategies to use when developing a product for a human body, what data to extract out of an existing anthropometric data set and how to create own data sets. The theme consists of one workshop assignment. During the workshop, data sets from http://antropometri.se/ and anthropometric measuring methods are used by the students to investigate a case.
Biomechanics	The biomechanical theme concerns loads applied to the body when undertaking a task and their effect on the body. Different methods to assess the risk for injuries are studied, e.g. biomechanical calculations, NIOSH lifting equation, and Snook tables.
Cognitive Science	The theme focuses on the importance for the product developer to take into account the users' cognitive limitations and differences, to create affordance and facilitate for the user.
Physical Factors	Physical factors include thermal climate, sound and vibration, light and radiation. These relate more to Ergonomics of production than to Ergonomics of products but are still an important part of the engineering profession. The content covers physiology, physics, the industrial environment, assessment, prevention and legislation.
Systems (HTO)	The systems perspective is emphasized through the introduction of the HTO-perspective, which highlights the interaction between the components humans, technology and organization. The students are assigned a task to reflect on an accident scenario and explain the background to the accident from an HTO-perspective.

During the second part of the course, the applied product development project, the students develop and present credible product concepts. The project aims at consolidating the students' understanding by implementing the theoretical knowledge in a relevant context. It constitutes an arena for developing practical skills in applying the theory and methods. In the project, the students have a wide choice of possible products to develop. The only instruction they receive is that they are to develop a concept for an everyday product used in a specific situation for a user with limited temporary or permanent capabilities.

In the project phase, the engineering students meet with occupational therapist students at the Faculty of Health Sciences. The DPD students then learn and benefit from the occupational therapist students' knowledge about users with special needs and methods to investigate these needs. The DPD students also train to communicate with other disciplines and are able to demonstrate their engineering skills. The latter is practiced when they reflect and give advice on the occupational therapist students' design projects, which take place in parallel with the engineering students' projects. As mentioned before, they apply a consultant role to each other, where the engineering students give advice on the technical aspects of a design solution, models and materials. The occupational therapist students, on the other hand, act as consultants regarding human activity in a certain context. The number of meetings between the engineering and the occupational therapist students vary from one year to another, from one to three meetings.

CROSSDISCIPLINARY MEETINGS – EXPERIENCES

Engineering students' view on the collaboration

The Design and Product Development students had mixed experiences about the collaboration. They put forward that the occupational therapist students possessed good knowledge about areas, in which the engineering students were lacking, for example about rheumatism, and that OP students could transfer their way of focusing on the user. The DPD students also appreciated the OT students' open way of thinking (not being attached to a common technical way of thinking). Perhaps a new product would not be a solution to a certain problem as there already existed different products on the market.

The OT students gave the DPD students new perspectives, for instance experimenting with themselves to test how it is with a certain lack of body functionality. They also gave the DPD students better overview of their problem area and how the users could be interviewed. The engineering students also put forward the importance of working with other professions, which was expressed as:

> *"Nice initiative to work with other professions. Nothing we have done before and which was relevant and important."*

Some students did not appreciate the collaboration, stating that it should be voluntary for the groups who were in need of collaboration with the OT students, and that it would have been more efficient to spend the time on project work. In some cases, the students also experienced that they had too little knowledge when meeting the OT students, and that it was difficult when the student groups were in different phases in their projects. Some students also perceived that there was lack of preparations from both student groups before the meetings.

The Design and Product Development students further put forward some suggestions for improvement of the collaboration between the engineering and the OT students:

- More time for collaboration, to present the projects and help each other (and that it would be easier if all students studied at the same campus)
- It is good if the student groups' projects are in the same phase when the students meet
- It is important to clarify what is expected from the students except working cross-disciplinary
- Questions from one student group to another should be sent between the groups in advance
- Creation of joint project groups consisting of a mix of engineering and OT students as the OT students have knowledge about humans and the engineering students have knowledge about technology and product development

Teachers' view on the collaboration

The teachers also experienced both advantages and challenges with the cross-disciplinary meetings. The OT teacher put forward that the students learn about their own competence and the other students' competencies. By that, they receive better preparedness to face challenges in a changing society. One of the engineering teachers also pointed out that the

DPD students learn about human needs that are not covered by the course book, and that they therefore have to collaborate with students from another field.

As a result of meeting with the occupational therapist students many engineering students modified the direction of their design project. The DPD students also received good advice on how to approach and learn about the user of the product that is to be designed. This was a clear positive outcome of the collaboration. It was also valuable with the teacher collaboration and learning about each other's discipline and courses.

One challenge from a teacher's view was the distance between the two campuses, which hindered an easy face-to-face group collaboration. The travelling between the campuses with whole student groups influenced the number of scheduled meetings between the students, down to only one scheduled meeting throughout the course. Some other issues that needed to be taken into account for the integrative teaching activity included the timing for the meetings between the student groups in relation to the design processes in their respective courses and how to prepare the students for the meetings.

Even though there were challenges to face, the AT teacher listed lessons learnt that could be of use in future integrative teaching activities:

- Personal meetings between teachers are important to identify touch points regarding competencies and within the different educational programs
- Keep the overall aim in mind – to prepare to students for a working life outside the university – and what is relevant to society
- The collaboration will vary over the years, avoid expensive common educational program plans
- Work in an informal way, start quickly, experiment and evaluate
- Focus on possibilities and keep an open dialogue with the students about preconditions for the collaboration

DISCUSSION

From the beginning the collaboration has had an integrated product development approach where the different student groups have clearly defined functions, or knowledge areas, as well as separate management structures (teachers and curricula) that must interact. This made it possible to create a collaboration scenario where the students met new knowledge cultures, different ways of solving problems, and management problems such as planning and communication issues. Thus, the collaboration relates to implementation of the CDIO Standard 2 and 3 (Section 3).

The design of the integration was challenging for the students and they had both positive and negative experiences. Positive as they discovered their own competence areas, learnt new ways of challenging their problems, and gained knowledge that was not included in the curriculum. The reported negative experiences were mainly related to how the management was managed after the change when splitting up in separate projects. The different student projects where then not coordinated so that they had the same user need or problem to solve, and the scheduled meeting time was perceived as too short.

From a teacher's perspective, the interviews showed that the engineering students were challenged to do something they were not used to and that they were mostly positive towards the meetings with the OT students. They also shifted their perspective on their chosen problem towards a more complex understanding, and they understood the need to explore user needs profoundly.

The authors also acknowledge that some further improvements can be done, such as coordinating the project tasks and course schedules so that the students more easily can exchange knowledge and experiences.

When setting up a cross-disciplinary collaboration it must be a win-win situation for both teacher and students alike to build a lasting relationship. This is in line with earlier reports about multidisciplinary courses, where it is important that all stakeholders (students, faculty, and administrators) benefit from the collaboration (Lovejoy and Srinivasan, 2002). The collaboration has been between two courses, not a joint one, implying that no faculty has had an economic influence over the other and there is no absolute obligation toward one another. The history of the cross-disciplinary collaboration demonstrates the need to be flexible and adapt to changes in both curricula and planning to maintain it. Overcoming administrative hurdles such as schedules, budgets, and facilities should be a priority. This paper has described the evolution of over 14 years of course collaboration between engineering and OT students and how it has influenced the learning outcome of engineering students that have participated in the courses.

According to the authors' experiences it is important to determine the level of epistemological and curriculum integration between the disciplines. In the lower levels of cooperation, such as intra-disciplinary, cross-disciplinary, and multidisciplinary, the epistemological integration is lower thus creating less potential friction between coordinating teachers. Depending on the course budget and faculty support, the curriculum integration may vary from no integration to a common schedule with joint grading. Interdisciplinary and transdisciplinary on the other hand creates a need for a full coordination of the different disciplines and also a need to create a common understanding of learning goals, joint grading and best practice to reach final results (Lovejoy & Srinivasan, 2002).

CONCLUSIONS

This paper describes a long-lasting teaching collaboration between the Faculty of Science and Engineering and the Faculty of Health Sciences at Linköping University, Sweden. The collaboration involves meetings between engineering students and occupational therapist students during in parallel ongoing design projects in separate course. They then train to communicate across disciplines and act as consultants. The engineering students give advice on the technical aspects of a design solution, models and materials, while the occupational therapist students act as consultants regarding human activity in a certain context. Some challenging issues that need to be dealt with include the timing for the meetings between the student groups, number of meetings and how to prepare the students.

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