THEME-BASED ASSESSMENT OF EDUCATION IN DESIGN AND PRODUCT DEVELOPMENT

Martina Berglund, Vanja Pavlasevic, Torbjörn Andersson, Johan Hedbrant, and Jonas Stålhand

Department of Management and Engineering, Linköping University, Linköping, Sweden,

ABSTRACT

One fundamental challenge in choosing an examination form to assess student achievements is to find an examination which, both encourages students to continuously elaborate the course content and constitutes a learning process itself. The objective of this paper is to share and reflect on the development and implementation of a new theme-based examination in a six credit course in Product Ergonomics given in the engineering programme Design and Product Development at Linköping University, Sweden. The course runs during four months and has two parts: one theoretical and one applied. The former focuses on theoretical ergonomic topics, models and methods while the latter is a project aiming at consolidating the students' understanding of the theory by implementing the knowledge in a product development case. To encourage the students to adapt a deep learning approach, the traditional written mid-term exam for the theoretical part was abandoned and another concept developed. In the new concept, the theoretical part was split onto six weekly themes. Each theme was introduced at the beginning of the week by high-lighting main theories and models followed by a group-work assignment to be elaborated on by the students during the week. The theme was examined at the end of the week through a short written exam and a seminar to discuss and reflect upon the theme. From a student perspective, the positive outcome of the theme-based examination was peer learning and a more active learning style. The students appreciated the theme-based structure of the course. Occasionally, some students commented that weekly examinations could be perceived as stressful. The teachers perceived the students to be more acquainted with ergonomics theory and methods which increased the quality of the course project. The reported theme-based assessment is one example of implementing among others the CDIO syllabus parts 2.2 and 3.1 and CDIO standards 8 and 11.

KEYWORDS

Examination, ergonomics, learning outcomes, educational goals, engineering competencies, CDIO Standards: 8, 11

INTRODUCTION

There are many different examination forms to assess students' achievements. Earlier studies show that the examination form in itself strongly influences the way the students study and learn (Biggs, 2003). Ramsden (2003) describes differences between students' study approaches and the outcome on students' learning. In a surface approach to studying, the students memorize facts and details without much reflection about the implications of their meaning (Marton and Säljö, 1976). In the deep approach to studying, on the other hand, the students reflect on the meaning of ideas and theories and try to relate them to real-life situations. Earlier studies show that deep approaches are related to higher quality outcomes

and higher students' satisfaction (Ramsden, ibid). One way to reach deep learning is to encourage the students to elaborate the course content continuously throughout the course. Another guiding principle is to develop examination forms which constitute a learning process in themselves (Hult, 1998).

This paper concerns a newly developed examination form in a course in Product Ergonomics which is taught to engineering students in the Design and Product Development Programme at Linköping University, Sweden. Ergonomics is a multidisciplinary field and it is defined by Corlett and Clark (1995) as: "The study of human abilities and characteristics which affect the design of equipment, systems and jobs. It is an interdisciplinary activity based on engineering, psychology, anatomy, physiology and organizational studies." In order to understand how ergonomics is related to design and product development, the course needs to cover a wide range of knowledge fields, such as anthropometry, biomechanics, methodology, cognitive science, physical factors, and systems thinking.

The course consists of two parts, a theoretical part and an applied product development project. Earlier, the theoretical part was examined through a traditional written mid-term exam, for which many students studied intensively a few days before the examination rather than continuously throughout the course. As a result, the ergonomics theories and models were not used to their full potential in the project. To encourage the students to adapt a continuous and deep learning approach throughout the course, a theme-based examination concept was developed and offered to the students as an alternative to the mid-term exam. The aim was to facilitate a deeper understanding of the subject, which is crucial to be able to apply principles and concepts in a new situation (Silén, 1998).

The objective of this paper is to share and reflect on the development and implementation of the new theme-based examination in the course Product Ergonomics at Linköping University, Sweden. The description of the students' perceptions of the course was based on a content analysis of a written individual assignment at the end of the course. In this assignment the students reflected on an applied project group work conducted in the course, their group process and learning outcome. The teachers' perceptions of the course were based on both individual and joint teacher team reflections.

EXAMINATION IN HIGHER EDUCATION

Examination may be divided into a number of assessment methods (Toohey, 1999):

- Objective tests,
- Essay examination,
- Open-book exams,
- Case study or problem-centred exams and assignments,
- Practical/professional tasks, and
- Production of works of art and performance.

As the examination strongly influences the students' learning, it is important to develop examination forms that are related to the course objectives. It is therefore important to formulate good learning objectives as well as to develop methods to assess to what extent the students reach these objectives (Lindberg-Sand, 2008). These assessment methods should be based on the qualifications needed for the students in the future. Looking at the required qualifications in their profession, engineering students will need to understand how models and theories may be applied in different contexts. In addition, they will have access to literature, why open-book examinations are more realistic and will probably encourage the

students to study with a deeper approach for the examination (Toohey, 1999). Furthermore, a deep approach may be encouraged through four principal factors (Biggs, 1989):

- An appropriate motivational context
- A high degree of learner activity
- Interaction with others, both peers and teachers
- A well-structured knowledge base

The engineering students' future needs of knowledge, skills and attitudes are described in the CDIO Syllabus v2.0 as *"Graduating engineers should be able to conceive-design, implement-operate complex value-added engineering systems in a modern team-based environment"* (Crawley et al, 2011). These goals should be the basis for learning objectives in individual courses, design of curricula and student learning assessment. The Product Ergonomics course described in this paper relates to the overall CDIO Syllabus v2.0 in all four main sections:

1. Disciplinary knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context

In developing new examination forms, however, two sub-sections were specifically addressed in order to promote the students' deep learning: 2.2 Experimentation, investigation and knowledge discovery and 3.1 Teamwork (Crawley et al, ibid).

DESCRIPTION OF THE COURSE PRODUCT ERGONOMICS

The reported experiences are from a six credit course in Product Ergonomics. It is a compulsory course for third year students in the engineering programme Design and Product Development at Linköping University. It is a compulsory course in Ergonomics in the programme and its importance cannot be underestimated particularly when considering that one of the students' main disciplines is human interaction in product development. It is therefore essential that their knowledge from this course is solid.

The course is designed to introduce the field of ergonomics and design. The course also provides a basic ability to evaluate the applicability of ergonomics design as a methodology on an individual case. The aim of the course is that the students should possess a number of knowledge areas and skills related to CDIO syllabus. After the course the student 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)
- analyse 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)

The course runs during four months (full autumn semester). During the theoretical part, the students mainly focus on getting to grips with theoretical ergonomic topics, models and methods. These covered topics are:

- The role of ergonomics in products and product development
- User profile and task analyses
- Qualitative and quantitative methods
- The product and the context
- Ergonomics (psychosocial and work organizational environment, physical workload, physical and chemical factors, man – technology system, safety – risk, laws).

The tuition is then structured around weekly themes where different knowledge areas are addressed in lectures, through discussion assignments, practical application exercises, assignments and seminars.

The product development project aims at consolidating the students' understanding by implementing the theoretical knowledge in a familiar and relevant context. In addition, the project provides practical skills in applying the theory and methods. The project is softly launched during the theoretical part of the course with a project planning phase so that the students can reflect on how to use the theoretical knowledge in their projects. During the project the students are trained to develop and present credible product concepts. In this phase the engineering students partly collaborate with occupational therapist students at the Faculty of Health Sciences at Linköping University, Sweden. 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.

DEVELOPED NEW EXAMINATION FORM

Ergonomics is, as mentioned before, a multidisciplinary field with a strong sense of reality that is well suited for case based work. The theoretical part was therefore organized into six weekly themes. Each week one theme was introduced in a lecture at the beginning of week, where main theories and models in the specific theme were presented and discussed. Case assignments where then also handed out to be elaborated in study groups. The selection of themes was based on available teaching weeks, the course book (Bohgard et al, 2011) and the different teachers' knowledge bases in ergonomics. The six themes and their contents are described in Table 1.

The specific theme of the week was then examined (in a short written exam) at the end of the week. For most themes, the group assignments were related to the written exam. However, two themes, Biomechanics and Systems, were of a more reflective character why the examination questions were introduced already at the introductory lecture. The written examination at the end of the week was always followed up by a short seminar to discuss and reflect upon the theme of the week. Each examination theme was related to a common context, a combined bar and restaurant, for which different scenarios and issues were brought forward.

In case of excusable absence, students were allowed a supplementary exam. Out of 69 students, 67 students chose the theme-based examination form. Of these, all but one passed the exam with an average of middle to high scores.

Table 1. Themes and content in weekly examination

Theme	Content
Anthropometry	The anthropometry theme focused on how to assess which anthropometric 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 consisted of one workshop assignment and one assessment at the end of the week. During the workshop data sets from http://antropometri.se/ and anthropometric measuring methods described in the course book where used by the students to investigate a case. These values where later used in the following biomechanics theme to create an understanding of how the two themes interacted. The theme's assessment concerned how to choose anthropometric strategies when redesigning a bar environment and how to create a method for collecting anthropometric data from bar attendees.
Biomechanics	The biomechanical theme concerned loads applied to the body when undertaking a task and their effect on the body. Different methods to assess the risk for injuries were studied, e.g. biomechanical calculations, NIOSH lifting equation, and Snook tables. The theme examination concerned the applicability of the different methods to assess the risk for lower-back injuries for bartenders.
Methodology	In the method theme the students were to learn about qualitative and quantitative methods within ergonomics. In the assignment they received a fictive inquiry from management of a company selling household appliances regarding how to investigate the user needs and perceived problems related to the use of one of the company's products.
Cognitive Science	The teaching and examination of the theme of cognitive science focused on getting students to realize that the product developer must take into account the users' cognitive limitations and differences in perception, ability, expectations, experiences, and create affordance using feedback, facilitate the user by using mental models, implement multimodality and relieve the user's memory functions.
Physical Factors	Physical factors include thermal climate, sound and vibration, light and radiation. They relate more to ergonomics of production than to ergonomics of products but are anyway an important part of the engineering profession. The content covers physiology, physics, the industrial environment, assessment, prevention and legislation.
Systems	The systems theme emphasized ergonomics from a systems perspective highlighting the interacting components humans, technology and organization. The students were assigned to reflect on an accident scenario at a restaurant and explain the background to the accident from a systems perspective. Furthermore, they were to suggest measures to increase safety and prevent similar situations to happen again.

STUDENTS' AND TEACHERS' PERSPECTIVES

Many of the students were positive towards the theme-based examination. The students put forward that they encountered many different scenarios and remembered a great deal from the different themes. Compared to other courses, the students had studied more continuously, which one of the students thought had resulted in deep learning. They also stated that they had been forced to read the course book and had learned to appreciate and

use it as an information source. Other statements referred to responsibility and class discussions, such as:

> *"The theme weeks with examination on Fridays made it easy to take responsibility for one's learning. During the weeks we discussed a lot with each other in class about the week's assignment and the discussions were very rewarding."*

Some students stated that studying for the weekly examination "took a lot of time and energy". The possibility to apply what had been learned during the lecture in practical assignments was perceived positive, however. One student described it as:

> *"There are good and convenient models /in Ergonomics/ which resulted in a clear structure. It has been stressful with examination each Friday, but I prefer that to having one examination on the whole course literature."*

Many students pointed out the advantage of having a firm knowledge base from the theoretical part that could be applied in their project work. They emphasized that they at the end of the project had thoroughly elaborated their product concept and had reached a convincing problem solution. The project work was, as earlier described, launched during the theoretical part and some students pointed out that they had reflected on the theories and models in each theme in relation to their ongoing project. At the end there were also challenging learnings, or as described:

> *"It was challenging to integrate all parts of ergonomics in the project. It was a challenge to develop a concept that was good in all fields of ergonomics as we sometimes noticed that an improvement in one area resulted in an impairment in another."*

From a teachers' perspective the division of the examination into themes seemed to result in more students studying all course topics, and most students performed well in the examination. In the biomechanical theme, for instance, the students were limited to write one page. The page limit forced the student to condense the theory and, thereby, shifted the focus from a repetitive knowledge to a thorough understanding of the key concepts. The idea was to promote a deep approach to learning (Biggs, 2003; Ramsden, 2003). Although such limits may hinder the student to take the deep approach (Ramsden, 2003), the results were positive. The mean score was 8 out of 10 and no student had below 5 points. In comparison, the matching question in the written mid-term exam the year before had a mean score of 4 points.

By distributing a group assignment after the introduction at the beginning of the week, the students were enticed to study the theme's theories and models, and to discuss their interpretation and application. In addition, the exam was open book and the students were allowed to bring the textbook, if desired. Both these factors indicated to the student that details and minor facts were not the essence when assessing their performance and this enabled a deep approach to learning (Biggs, 2003).

The examination themes had different approaches and perspectives to a specific context, a combined restaurant and bar. Through that the teachers had a common context, from which different scenarios could be developed. A benefit for the teacher team was that the tutorial in the various stages resulted in a more advanced level providing direct effect on the parallel student project level. The theme based learning also gave the teachers a possibility to quickly change the order of the themes without interfering with the overall content. This made the syllabus more robust to adjustments.

The final seminars after the weekly examination showed varying results. Sometimes the students were not very active and expressed temporary indifference due to exhaustion. They also stated that they had discussed everything thoroughly before the exam. Other occasions became more successful when the students indeed took the opportunity to discuss and reflect on the theme.

The teachers also experienced that the students had a deeper understanding of the importance of also having an ergonomic viewpoint in the product development process (cf Ulrich and Eppinger, 2004). The students appeared to be more acquainted with ergonomics theory and methods in the planning of their course projects and worked more systematically with the different course topics than during earlier years.

DISCUSSION

The aim of developing the theme-based examination was to encourage the students to study continuously and reach a deep approach to learning. Many students reported a positive outcome with peer learning and a more active learning style through their own searching for useful theories and models for the specific themes. They read more in the course literature and searched also knowledge from other sources that were related to their product development project. The students appreciated the theme-based structure of the course, although some students commented that weekly examinations could be perceived as stressful.

For many students this was a new way of acquiring knowledge and it demanded an adaption of their learning style. Nevertheless, the new examination form succeeded in encouraging deeper learning among the students, which was also noticeable in their product development projects. This was achieved through group assignments, peer learning, and a high degree of learner activity, all advocated by Biggs (1989) to encourage deep learning. Furthermore, the teachers put effort into presenting and teaching well-structured themes to facilitate for the students to develop a firm knowledge base. In encouraging deep learning through the choice of a theme-based examination, the two CDIO syllabus parts “2.2 Experimentation, investigation and knowledge discovery” and “3.1 Teamwork” were addressed.

The high degree of learner activity is also related to the CDIO standards, in particular the standard for Active Learning (CDIO Standard 8), as the students were stimulated in different ways to get involved to pursue and develop their own learning. This was done through collective processing of questions that prepared students for each part of the examination. In answering questions, students needed to create their knowledge through both exploration and experimentation, by academic search of relevant knowledge and by applying it with a critical attitude.

The theme-based examinations were modularized, but at the same time related to a certain context (the combined bar and restaurant) which could be regarded from different perspectives. The joint context facilitated for the students to retrieve thoughts from earlier examination moments, which likely resulted in a better overall picture of the theoretical part of the course. The students were allowed, as earlier described, to bring their course literature to the written exam. By that, minor details could be looked up when solving problems. Memorizing facts were thus not tested, but skills to solve various ergonomics problems in more real life looking work settings. This addresses the CDIO standard for Skill Assessment (CDIO Standard 11).

From a teacher perspective, some practical advantages with the theme-based examination included the possibility to quickly change the order of the themes without interfering with the overall content. This flexibility may also free up resources to identify opportunities for further

improvement of supervision and teaching. Furthermore, as it is a written examination the teachers may also benefit from the overall examination structure of having several themes related to a certain context. It is quite possible to keep the context and change the scenarios or keep the scenarios and change the context. This creates a potential diversity for future course examinations.

Ergonomics is, as stated earlier, an interdisciplinary field suitable for a systems perspective. How does an integrated learning match with theme-based examination? In the beginning of the course, the background to and the systems perspective of ergonomics was described, followed by a division into the different weekly themes. By focusing on one at a time, the different theories and models were highlighted in practical use of the week's assignment. Here, it became evident to the students that there were specialist knowledge fields in each theme, which were far from common sense as perceived initially by some students. After these weekly concentrations on specific themes, the systems perspective were once more highlighted in a final systems theme bringing forward the interaction between humans, technology and organization, and finally the systems perspective was being elaborated in the students' project work.

The theoretical knowledge gained by the students were visualized in the product development projects, as the perspectives and methods from the theoretical part were integrated in the project work and used for relevant problem solving situations and analyses. The physical factors did not stand out in the project work. The importance of these factors, however, becomes more important in later phases of the product development process when developing the production system and its processes. Integrating ergonomics in design and product development is sometimes perceived as challenging for the engineering students (Woodcock and Galer Flyte, 1998). The experiences from the course may serve as one example of how to work systematically with the knowledge field of ergonomics, promote a deep approach to learning and integrate ergonomics knowledge in the engineering students' product development projects.

CONCLUSION

This paper has described and reflected upon the new theme-based examination in the course Product Ergonomics at Linköping University, Sweden. Instead of examining the theoretical part in a traditional written exam at the end of the lecture series, deep learning was encouraged through a theme-based course. Each theme was introduced, elaborated on by the students in practical group assignments and examined during one week. The students perceived the theme-based examination as mainly positive although some students thought it stressful with the weekly exam. The students reported better learning in ergonomics and expressed high confidence in using its models and theories in a practical context. This was also demonstrated in a systematic use of ergonomics knowledge in the students' product development projects. The reported theme-based assessment is one example of implementing the CDIO syllabus parts 2.2 and 3.1 and CDIO standards 8 and 11.

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BIOGRAPHICAL INFORMATION

Martina Berglund, Ph.D. is an Assistant professor at the Division of Quality Technology and Management, Department of Management and Engineering at Linköping University, Linköping, Sweden. She is the director of the Human Factors Network in Sweden and collaborates in teaching with KTH Royal Institute of Technology and the School of Engineering at Jönköping University. Her current research focuses on the cultural impact on global product realizations, ergonomics/HTO, and quality development and management.

Vanja Pavlasevic, M.Sc. is a lecturer at the Division of Machine Design, Department of Management and Engineering at Linköping University, Linköping, Sweden. She is the examiner of the six credit course in Product Ergonomics in which the new theme-based examination form described in this paper is offered.

Torbjörn Andersson is a Ph.D. student and lecturer at the department of Management and Engineering at Linköping's University, Sweden. His current research focuses on how industrial designers make strategic decisions when doing the design for a commercial product. He is also involved in the curriculum development of the Design and Development program at the institute of Machine Engineering.

Johan Hedbrant, Ph.D., Lic.Eng., Lic.Med.Sc. is a research engineer and teacher at the Division of Applied Thermodynamics and Fluid Mechanics, Department of Management and

Engineering, as well as the Faculty of Educational Sciences at Linköping University. Current research relates to interest and attitudes to science and technology in school and is financed by Swedish Energy Agency and Swedish National Agency for Education.

Jonas Stålhand, Ph.D. is an Associate Professor at the Division of Mechanics, Department of Management and Engineering at Linköping University, Sweden. His current research focuses on mathematical models in biomechanics. He is also giving basic and advanced courses in mechanics and ergonomics.

Corresponding author

Dr. Martina Berglund
Quality Technology and Management,
Dept of Management and Engineering,
Linköping University
SE-581 83 Linköping, Sweden
46-13-281530
martina.berglund@liu.se