Multidisciplinary frameworks are needed to develop products that fit the human. Ergonomics is a multifaceted field that encompasses physical, cognitive and organizational aspects, and it is therefore a suitable subject to be taught to design engineering students. The objective of this paper was to describe and reflect upon how a systems perspective on Ergonomics is developed and conveyed in a course in Product Ergonomics to engineering students at the Design and Product Development (DPD) programme at Linköping University, Sweden. The paper is based on the authors’ experiences from teaching the course in Product Ergonomics as well as on 52 students’ written reflections about their view on Ergonomics before and after taking the course. Means and ideas for teaching Ergonomics with a systems perspective included organizing a theoretical introduction into weekly themes and thereafter integrating and applying these themes in a product concept project under supervision of a multidisciplinary teacher team. The paper also reflects on how the systems perspective of Ergonomics is planned for and realized in the intended, implemented and attained curriculum.

Practitioner Summary: Ergonomics is a multidisciplinary field which is suitable for product development but also may be difficult to grasp. This paper describes and reflects upon how Ergonomics was taught to facilitate the development of a systems view on Ergonomics for engineering students at Linköping University, Sweden. Means for achieving this were to: organize the course in weekly themes in which different knowledge areas within Ergonomics were elaborated, integrate these knowledge areas in a product concept project, and have a multidisciplinary teacher team.

Keywords: systems perspective, university education, product design

1. Introduction

In design of products, services and organizations, different multidisciplinary frameworks are used such as Human Centred Design (ISO-standard, 2010) and User Experience (Roto et al, 2010). Although the term Ergonomics has often been associated with physical aspects and individual factors (Wilson, 2000), it is a multidisciplinary field including e.g. physical, cognitive and organizational aspects, each requiring their own specialists. Dul et al (2012) argue that Ergonomics and Human Factors with its systems approach and design focus has great potential in designing different systems. Wilson (2014) describes six overlapping features that are needed in a systems Ergonomics/Human Factors (E/HF) approach: systems focus, context, interactions, holism, emergence and embedding.

With respect to designing products that fit the human, one challenge is to take into account a multifaceted perspective of Ergonomics. How, then, may this wide, systems perspective be realized in university teaching and understood by the students? Earlier studies on higher education show that there may be gaps between the intended, implemented/enacted and attained curriculum (Travers, 1989; Galton and Eggleston, 1979). The teachers may have a vision of conveying the systems perspective of Ergonomics to the students in the intended curriculum, which is described as the course aims. However, there may be a gap to what is implemented in the course as well as to what is finally attained by the students. The latter is not the least challenging as individual students have different abilities, views on knowledge as well as different learning styles, which occasionally is experienced as “different worlds in the same classroom” (Perry, 1985).

The objective of this paper is to describe and reflect upon how a systems view on Ergonomics is developed and conveyed in a course in Product Ergonomics to engineering students at the Design and Product Development (DPD) programme at Linköping University, Sweden. It is a compulsory, six-credit
course for third-year students, which is designed to introduce the field of Ergonomics and Design from a theoretical as well as an applied perspective.

The systems perspective in this paper refers to the multidisciplinary character of Ergonomics in itself, but an overall systems view is also taken on how Ergonomics appears and is integrated in the engineering programme as a whole. The paper contributes to knowledge about how to develop Ergonomics teaching with a systems perspective in terms of highlighting the intended, implemented and attained curriculum of Product Ergonomics (Travers, 1989).

2. Design and product development

In today’s competitive market, there is an increased demand on the engineers’ skills regarding product development. They need to be able to solve technical and functional problems as well as usability issues and create user experiences in order to make successful products and services. To meet these demands on future engineers, universities have created a new type of education that integrates classical engineering subjects such as Mathematics and Engineering with Ergonomics, Industrial Design and Interaction Design. They are often referred to as Design Engineering (or Industrial Design Engineering) programmes. The goal is to educate creative product development engineers that have a human centred approach (ISO-standard, 2010) and an understanding of aesthetic values when developing new products and services.

The choice of integrating industrial design into engineering programmes stems from the idea that industrial design, by nature, handles indistinct problems (Cross, 2003). At the same time it has to take into account for situations with conflicting demands (requirements) and multiple solutions. Industrial design education also has a tradition of being user centred and more ‘hands-on’ through making sketches and models. It also focuses on exploration and the development of many diverse ideas in the design process. Engineering educations are traditionally more focused on solving technical problems that deliver one or a few rational solutions.

In practice, students are given broader scopes to explore in courses, and they have to find information from several knowledge fields, thereby linking Design, Engineering and Ergonomics. These broader scopes demand greater understanding of overall systems, and the application of different knowledge fields can create conflicting needs and demands which the students have to resolve. Ergonomics and systems approaches to product development processes gradually increase throughout the curriculum to give students theoretical, methodical as well as practical knowledge about human-centred approaches.

3. Method

This paper is based on the authors’ experiences from teaching and developing the course in Product Ergonomics during three years. Data about the students’ view were collected through 52 individual written reflections about the course. In the assignment the students were asked to reflect on their view on Ergonomics (meaning, content and application) before and after the course. Furthermore, the students were assigned to reflect on Ergonomics in the product development process.

4. Ergonomics in the DPD-programme

The DPD-programme at Linköping University is a new programme based on the Mechanical Engineering programme. In the programme description there are three statements that particularly relate to the field of Ergonomics (liu.se, 2015):

- A DPD-engineer should have a multidisciplinary approach in which knowledge and competence from different areas is crucial for a successful product development.
- The DPD-engineer should have the ability to apply a systems perspective to model, analyse and develop technical systems and processes. This implies being able to define systems limits, make abstractions, identify both the whole system and subsystems, describe the interaction between these entities and prioritize trade-offs.
• An engineer from Linköping University should take responsibility for the role of technology in society in relation to economic, social and ecological sustainable development.

In the DPD-programme there is a mix of traditional engineering courses and industrial design, ergonomics and product development courses. Ergonomics concepts are first introduced in the introductory course Design and Product Development, see Figure 1, on a basic and practical level. Here, the students carry out a project where they investigate a usability problem, design, and build a prototype in the workshop. The main Ergonomics concepts that are introduced in the course are User Centred Design (UCD) and anthropometry. In the Usability course, UCD is further explored and von Hippel’s (Churchill, 2009) concept of Lead User and Co-creation is introduced. Ergonomics as an individual theoretical subject and methodological approach is first introduced in the course Product Ergonomics in the third year. Figure 1 shows an overview of the DPD-programme up to Bachelor level and demonstrates how prior courses content underlies two of the themes (Method and Biomechanics).

5. Results

5.1 Description of the course Product Ergonomics

As mentioned, Product Ergonomics is a six-credit course taught to third year students in the engineering programme Design and Product Development at Linköping University. It is a compulsory course that provides a basic ability to evaluate the applicability of Ergonomics design as a methodology on an individual case.

The course in Product Ergonomics runs during the full autumn semester, and it consists of two parts: a theoretical introduction and an applied product development project. During the theoretical introduction, the students learn theoretical ergonomic topics, models and methods.
5.1.1 Part I – Theoretical introduction

The multidisciplinary field of Ergonomics is addressed in different weekly themes: Physical Factors, Anthropometry, Biomechanics, Cognitive Ergonomics and a concluding Systems theme where the HTO-concept (Human, Technology and Organization) is applied. In addition to these topics, one week is devoted to methodology in order to prepare for the students’ coming project work. Each theme is addressed in lectures, group assignments, and seminars.

Ergonomics is, as mentioned, an applied area which is well suited for case-based work. Each week the current theme is introduced in a lecture at the beginning of week, and main theories and models in the specific theme are presented and discussed. Group assignments are then handed out to be elaborated on in study groups. The selection of themes has been based on available teaching weeks and the course book (Bohgard et al, 2011). Their contents are described in Table 1.

Table 1. Weekly themes and content.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropometry</td>
<td>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 <a href="http://antropometri.se/">http://antropometri.se/</a> and anthropometric measuring methods described in the course book are used by the students to investigate a case. The data sets are later referred to in the following biomechanics theme to create an understanding of how the two themes interact.</td>
</tr>
<tr>
<td>Biomechanics</td>
<td>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.</td>
</tr>
<tr>
<td>Physical Factors</td>
<td>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 anyway an important part of the engineering profession. The content covers physiology, physics, the industrial environment, assessment, prevention and legislation.</td>
</tr>
<tr>
<td>Cognitive Science</td>
<td>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.</td>
</tr>
<tr>
<td>Systems</td>
<td>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 to reflect on an accident scenario and explain the background to the accident from a systems perspective.</td>
</tr>
<tr>
<td>Methodology</td>
<td>In the method theme the students learn about qualitative and quantitative methods within Ergonomics. In this theme the student also start reflecting and planning for their future product development project by suggesting the scope. Here they define the human (the user), an object (which will be developed or modified), the task which is performed and the context (in which the human uses the object to perform a task).</td>
</tr>
</tbody>
</table>

5.1.2 Part II – Product development project

In the second part of the course, the students work with a product development project, in which they are trained to develop and present a credible product concept. The project aims at consolidating the students' understanding by implementing the theoretical knowledge in a relevant context. In addition, the project constitutes an arena for developing practical skills in applying the theory and methods.

The project is launched at the end of the theoretical introduction. During the second part of the course the students work independently in groups of four students with their projects, with support from teachers.
Four supervision hours are scheduled each week, and each project’s status is presented every two weeks in larger groups. In this part of the course the students also have a scheduled consultation with occupational therapist students at the Faculty of Health Sciences at Linköping University. The engineering students then learn and benefit from the other students’ knowledge fields. They also train to communicate across disciplines.

5.2 Teacher team with different disciplinary backgrounds

The role of the teacher team is to support the students’ system thinking and reflection on the relevance of the different areas within Ergonomics with respect to their specific project. To reflect the width of the subject and to incorporate the multidisciplinary vision of the programme, the teacher team consists of six teachers from different disciplines. Each teacher is proficient within his/her discipline but, in some cases, the expertise is partly overlapping between the disciplines, too. This allows the team to cover the space spanned by the weekly themes in Table 1. It also provides legitimacy since the teachers are affiliated with subjects previously studied and the course content is firmly rooted in the knowledge base acquired by the students in those courses. This was expressed by one student as:

“It was a fun insight that classical mechanical calculations were possible to use to estimate loads on different parts of the body.”

Each project group is assigned a pair of teachers for supervision. These teachers are responsible for supporting the group as the project progresses, but all teachers are available for supervision with respect to their specific field of competence if needed. This approach highlights the multidisciplinary nature of Ergonomics to the student and makes it clear that aspects from several disciplines must be taken into account to design user friendly products.

5.3 Views on Ergonomics and the course

5.3.1 Student views on Ergonomics

In the written student reflections about their view of Ergonomics before and after the course, many of the students stated that their view of Ergonomics had changed considerably. Before the course, Ergonomics was considered as ‘common sense’ and something related to hard labour. Ergonomic products were associated with design for injured and disabled people or professionals working with tools all days. The students also described their initial view on Ergonomics as:

“When the course just had started, I didn’t really understand how I, in my future work with design and engineering, could have any use of Ergonomics.”

“I thought that Ergonomics was something necessary evil at workplaces and public places. That it was something that was needed due to laws and regulations, and nothing that was the basis for a complete product.”

“I regarded Ergonomics as something that one started to think of after a long time in [at the end of, authors’ note] the product development process, when it was time to realise the product.”

“Before, I was part of the group of people who knew what Ergonomics was all about, but who in reality only had seen a small part of the full picture.”

“I underestimated Ergonomics…that it was an additional thing, a less important part of the whole product development process…that you developed a product and then added Ergonomics afterwards.”
At the end of the course, the students described that they had gained a much deeper understanding of the complexity of Ergonomics, and that it had changed their view on products in their daily lives. They also described Ergonomics in relation to their future role as engineers and the product development process:

“Ergonomics is very complex and one has to consider the whole and put the user in focus.”

“As a future product developer this course is one of the most rewarding so far as it has given a new dimension to product development. I think that Ergonomics arguments for the design of a product have at least the same weight as the appearance and strength of materials.”

“The systems thinking in the course is a rather unusual ingredient in the DPD programme…It easily happens that technicians indulge too much in the technical solutions.”

“The fact that I now can develop a theoretical background to motivate my design is something that I have missed, but that I now can bring into future projects.”

“Today I can see the different areas in Ergonomics as tools in a toolbox…”

“From the different areas in the course, one learns to see things from different perspectives, but also that different perspectives must consociate. In my opinion one must look at the whole when working with Ergonomics in order to say that something is ergonomic.”

“Ergonomics encompasses so many more parameters than I had ever thought and there are therefore many different application areas.”

“Now afterwards it is almost embarrassing that one has had such insufficient knowledge about a field which is applied in many parts in a product development process.”

“I think that the engineer’s role is to see Ergonomics from a holistic perspective where consideration should be taken to the interaction between the human, technology and organization.”

5.3.2 Student and teacher views on the course

In summary, the students clearly stated that they had learnt a great deal during the course and that the course structure was suitable. However, at the final evaluation of the course many of them also emphasized that the workload was too high for a six credit course.

A major challenge in the course was a discrepancy in the expectations on the course between students and the teachers. Up to the third year, the students primarily had taken basic engineering courses characterized by a well-defined set of concepts which had to be mastered and a written exam at the end. The course in Product Ergonomics significantly deviated from this pattern, however, and the content could not be understood in terms of the ergonomic methods taught. At the beginning of the course, many students used a learning style which had been successful in previous courses, and tried to identify the methods and concepts needed to pass. When they failed to find such cues and were forced to adjust their learning styles, frustration and uncertainty spread. During the project, the multidisciplinary nature of Ergonomics helped the students to adjust their learning styles: the complexity and existing interconnections required a holistic approach.

6. Discussion

The objective of this paper was to describe and reflect upon how a systems view on Ergonomics was developed and conveyed in a course in Product Ergonomics to engineering students.

The intended, implemented and attained curricula (Travers, 1989) in relation to development of a systems perspective are shown in different ways. The intended curriculum for the whole DPD-programme is represented by the statements that the DPD-students should adopt a systems perspective to develop
technical systems and processes and apply a multidisciplinary approach as this is crucial for successful product development. This is in line with Ergonomics as a multidisciplinary domain with a clear systems approach (Wilson, 2014) and the aim of the course. In the programme description it is also stated that the engineers should take responsibility for a sustainable development in society to which ergonomics can make a strong contribution.

Regarding the implemented curriculum, the main issue is how to cover the different areas within Ergonomics in a multidisciplinary approach where the students develop a systems view. One challenge is how to reflect this in the design of the course. In this case, it was first realized by teaching weekly themes in the theoretical part of the course, where the students could concentrate on one sub-discipline at a time. This facilitated their understanding that Ergonomics encompasses several specialist areas. Second, in this course the development of a systems view was deepened in their projects where the students needed to combine and apply different areas to develop a product concept that fit the human. In the course, several of the overlapping features that are needed in a systems Ergonomics approach were addressed (Wilson, 2014). The systems perspective and the focus on the interaction between its parts were presented in the introduction of the course, deepened in the HTO-theme and further developed in the project. The features context, holism and emergence were mainly addressed in the project, in which the students needed to gain thorough understanding of the real context of the product they intended to develop, a holistic view helped them to identify other possible consequences of their product than first envisioned, and the students learnt about emergent properties of systems in their studies of real users behaving differently than intended.

Having a multidisciplinary teacher team proved to be advantageous to demonstrate the width of and the need for different specialists within Ergonomics, but is may also constitute a challenge as the teachers themselves need to have common systems view to convey to the students during the theoretical introduction as well as during supervision of the student projects.

Another potential challenge related to teaching Ergonomics within an engineering programme is how to convey the systems view to the students as they tend to prefer ‘teach-to-test’ courses instead of adopting a broad systems view (Ramsden 1992). Understanding the different parts in relation to the whole is a difficult message to convey to the students because it requires a certain academic maturity to appreciate it (Perry, 1985). In this course, a mid-term exam and the project report seemed to be a major source of stress to many students, and, in particular, the marking as it was more difficult for the students to forecast the knowledge and skills needed for a ‘typical’ examination. A likely reason for this is that the assessment always defines the actual curriculum from the students’ point of view (Ramsden, 1992). When the exam is no longer about mastering a well-defined set of concepts but to understand how these concepts interact and contribute to the whole, the ‘unwritten rules’ of marking are changed and the transparency is lost to many students. As a consequence, they do not know what is important. Unfortunately, this situation persists until the student has reached the academic maturity required. It is, therefore, of the utmost importance to design the course and assessment scheme to be challenging but not overwhelmingly difficult. This would help most students to develop this maturity and to abandon their previous learning styles (Perry, 1985).

A picture of the attained curriculum was shown in the students’ reflections of the course, in which they described that their initial view on Ergonomics had been narrow and that Ergonomics after the course encompassed many specialist areas, all having their own specific methods, being far from a field where one could use ‘common sense’. Many students also described how their systems view on Ergonomics was deepened in the project, and that it was important to have a holistic view with different perspectives and not forget the interaction between different parts of the system. It was also interesting to note the changing opinion about the potential of Ergonomics in the product development process – from an initial underestimation of its value, to Ergonomics becoming a necessary part to develop products that fit human needs.

Product development processes take place in a competitive environment, where technical and functional problems must be solved and usability must be taken into account to make successful products. Ergonomics has an important contributing role in these processes, but its potential depends on how well the Ergonomics perspective is integrated in the product development process. One important step is to educate future design engineers. This paper has discussed the value of including Ergonomics in one engineering programme at Linköping University, but also some challenges that needed to be handled. Furthermore, there are future issues that need to be addressed. What parts (if not all) of the multi-disciplinary Ergonomics are important to convey to future design engineers, in today’s education and that of tomorrow? How can teachers promote further development of a systems view within courses and educational programmes? The
latter is challenging as it directly relates to the need for course designs and examination forms which differ from the intra-disciplinary engineering subjects to which the students are used. Finding ways to succeed in this would be one way to contribute to Ergonomics being a natural perspective for design engineers.

7. Conclusions

This paper describes and reflects upon how a systems perspective on Ergonomics was developed and conveyed in a course in Product Ergonomics to design engineering students at Linköping University, Sweden. Means and ideas for teaching Ergonomics with a systems perspective included organizing a first theoretical introduction into weekly themes, where each theme was introduced and elaborated on. These sub-disciplines of Ergonomics were thereafter integrated and applied in a product concept project, in which the student groups worked independently under supervision of a multidisciplinary teacher team. In the course design several overlapping features needed in a systems Ergonomics approach were addressed, and there was congruence in relation to the systems view in the intended, implemented and attained curriculum. Challenges in teaching a systems perspective on Ergonomics included the need for the teachers to have a common systems view to convey to the students during all course activities, the importance of careful design of the course and examination forms, and the students’ reluctance to face a new type of course in their engineering program where they need to adopt a new learning style. Finally, the findings of the paper demonstrate the value of including Ergonomics as an individual subject in a design engineering programme as it thoroughly changes the students’ view on what should be included in a product development process that ensures realization of products that fit the human.

References


