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## Emphasizing the interactive systems view in a master's programme in Ergonomics and HTO

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Ergonomics spans over several disciplines and carries a strong potential in designing and improving systems performance. However, from an educational perspective, bringing forward the systems perspective may be challenging from different point of views e.g. what areas of Ergonomics should be taught and in what way and how should the systems perspective be realized in an educational setting. The aim of this paper is to highlight experiences and lessons learned when emphasizing and developing an interactive systems perspective within a master's programme in Ergonomics and HTO (Human, Technology, Organization) at the Royal Institute of Technology (KTH), Sweden. The interactive systems perspective is conveyed through a separate HTO-course to emphasize the systems perspective and a developed interdisciplinary approach. It further pervades the programme from selection of students, pedagogical structure of the programme and the teachers' multidisciplinary backgrounds. Although working with a full educational programme gives substantial room for manoeuvre, some experiences and ideas from this education may serve as inspiration in other ergonomics and human factors educational contexts.

**Practitioner Summary:** Ergonomics is a multidisciplinary field, which contributes to developing a systems view to design products and systems. Bringing forward the systems view in an educational setting, however, may be challenging. This paper highlights experiences and lessons learned when emphasising and developing an interactive systems perspective within a master's programme in Ergonomics and HTO (Human, Technology, Organization) at The Royal Institute of Technology (KTH), Sweden. The interactive systems perspective is developed through student and teachers with different academic backgrounds, linking between different courses in the programme, and an HTO-course, which emphasizes the systems perspective in Ergonomics.

**Keywords:** teaching, multidisciplinary, humans, technology, organization

### 1. Introduction

Ergonomics is a multidisciplinary discipline, which spans over several fields and carries a strong potential in analysing, designing, and improving systems performance. While having the potential of achieving a systems perspective, the broad content of Ergonomics may also make it unclear (Karlton et al, 2014). Dul et al (2012) argue that Human Factors and Ergonomics (HFE) has great potential to contribute to the design of systems and products, but to reach its full potential there is a need to promote the education of high-quality HFE-specialists. One way is to emphasize a systems perspective which is here referred to as "the idea of a set of elements connected together which form a whole, showing properties which are properties of the whole, rather than the properties of its element parts" (Checkland, 1981).

Within Ergonomics there is a long history of focusing interactions between people, products and environments, especially regarding redesign of interfaces, workspaces or work activities. However, Wilson (2000, 2014) argues that a stronger focus should be on the interaction between the systems' constituents rather than on specific activities or entities. In designing complex and multi-faceted interacting systems (Wilson, 2000), more discussion and integration between the different sub-disciplines of Ergonomics also need to be stressed (Carayon, 2006).

As the complexity in operations and development of activities in production and product development systems increases so does the demand for interaction of human, technological and organizational inter-

faces. At the same time the societal demands for sustainable work systems increase (Docherty et al, 2002). This indicates the importance of addressing contextual factors and the characteristics of the human-machine interaction in the actual organizational setting to enhance usability of technological products and production systems Karvowski et al (1994).

From an educational perspective, bringing forward the systems perspective may be challenging from different point of views: what areas of Ergonomics should be taught and in what way; how should the systems perspective be realized in an educational setting; is there any literature to support the systems perspective; and how do we find teachers with a combination of a broad and deep knowledge of the multi-faceted discipline of Ergonomics?

The aim of this paper is to highlight experiences and lessons learned when emphasizing and developing an interactive systems perspective within a master's programme in Ergonomics and HTO (Human, Technology, Organization). The master's programme is taught at the Swedish Royal institute of Technology (KTH) and the systems perspective is developed by different means. One way of highlighting the systems perspective is by naming the programme Ergonomics and HTO. The HTO-concept has its origin within the nuclear power industry safety but is today a well-established concept in Sweden that has spread to other domains (Karlton et al, 2014). It includes the interactions between the subsystems Humans, Technology and Organization, and it is strongly related to systems performance, safety and health issues. Experiences from applying the HTO-concept in both industrial settings and academic teaching show that it constitutes a pedagogical tool to facilitate the systems understanding (Karlton et al, *ibid*).

The concept of 'interactive systems' refers to a focus to bridge the sub-disciplines of Ergonomics (Moray, 2000; Carayon, 2006), in this case reflected in the different courses in the master's programme. This interactivity is achieved through the linking role of a separate HTO-course and the pedagogical approach with integration of courses and their examination, instead of teaching independent subjects within Ergonomics and letting the student develop their individual systems view.

## **2. Method**

Material for this paper is based on the authors' experiences from teaching and continual development of the master's programme in Ergonomics and HTO as well as course evaluations during five rounds. Data were also collected through a questionnaire to alumni students in spring 2013. The questionnaire was designed with answers in free text embracing questions about how the students experienced the programme given their educational background and the relevance according to their educational and/or professional background.

## **3. Master's programme description**

The overall aim for the master's programme is to provide a holistic view on humans at work and the interplay between humans, technology, organization and the environment. This holistic view is described in the knowledge the students obtain in the programme:

The students will have knowledge about:

- how to analyse work and work activities as well as how to design workplaces which promote safety, health and wellbeing for the individual and operations performance (e.g. productivity, absence of disturbances, and quality).
- how to manage projects and change processes, especially how to integrate Ergonomics and HTO in development processes.
- regulations and professional roles, such as consultants, experts and facilitators.
- the interests of different stakeholders in working life, the importance of cross-disciplinary collaboration as well as how Ergonomics specialists and practitioners may collaborate.

The students may choose to study the master's programme in one or two years. For all students the first year includes five courses of six credits:

- Humans, Technology, Organization
- Research Methods and Study Design
- Cognitive Ergonomics
- Organization, Change Management and Work Environment Legislation
- Workload Ergonomics

During the second year, the half-time students carry out a project work and their final degree project in Ergonomics. Those students who fulfil the whole master's programme in one year carry out the project work and final degree project in parallel with the other courses.

Each course lasts five to six weeks with some overlap between the courses, see Table 1. The programme is a mix of distance learning and ten course meetings during two to three days each. During the course meetings there are lectures, seminars, discussions and different types of examination activities depending on the learning goals. Except for individual studies the distance learning between the course meetings includes both group and individual hand-in tasks.

Table 1. Distribution of courses for half-time studies.

| Courses                    | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <u>1<sup>st</sup> year</u> |     |     |     |     |     |     |     |     |     |     |     |
| HTO                        |     | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   |
| Method                     |     |     | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   |
| Cognitive Ergon.           |     |     |     | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   |
| Org                        |     |     |     |     | ■   | ■   | ■   | ■   | ■   | ■   | ■   |
| Workload Ergon.            |     |     |     |     |     |     | ■   | ■   | ■   | ■   | ■   |
| <u>2<sup>nd</sup> year</u> |     |     |     |     |     |     |     |     |     |     |     |
| Project work               |     | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   | ■   |
| Degree project             |     |     |     |     |     |     | ■   | ■   | ■   | ■   | ■   |

## 4. Findings

### 4.1 Pedagogical setup

The systems perspective in the programme is developed and conveyed through the organization of the whole programme; the selection of courses, how these interlink, and examination forms.

The programme begins with the course Human-Technology-Organization (HTO) that outlines the systems perspective by focusing the interaction between system constituents and tying together the different areas in Ergonomics. It also serves as a uniting theme throughout the programme to stress the application of the systems perspective/interactions in the other courses. It helps the students to grasp the multifaceted field of Ergonomics. The course consists of the development of Ergonomics and HTO concepts, systems perspectives; and practical applications based on a systems approach from different viewpoints. The course is divided into two parts, a first part to introduce a systems perspective and a second part at the end of the academic year in which the systems perspective is deepened through analyses and reflections on cases.

When continuing with the other courses (Cognitive Ergonomics; Organization, Change Management and Work Environment Legislation; and Workload Ergonomics), the relation to the systems perspective is continually emphasized. Even though these have specific topics, the relation to the other areas of Ergonomics and the overall HTO-concept is discussed to facilitate the students' understanding of Ergonomics from a systems and interaction perspective. The students are thereby trained to see how the specific area in focus is influenced by other areas within Ergonomics and how it in turn influences other areas.

The programme as a whole as well as the separate courses has over the years received a stable high rating in the course evaluation and the HTO course has been ranked as the most outstanding course.

A number of different examination forms are applied in the programme. The systems perspective is brought forward also here, by referring in specific examination tasks to issues in other courses or the overall HTO-concept.

#### **4.2 Students with different academic backgrounds and mix of full-time and half-time students**

The students may have a technical, health science or behavioural science background. The aim is to have one third of the students with each background. However, during the years there has been a larger group of students with a health science background and less with a technical background. Approximately half of them are younger students coming directly from their undergraduate studies, and the other half are students who have worked for several years and now study half-time while continue working. The professional group of students includes specialists in certain fields, consultants, self-employed people, teachers, representatives for Swedish authorities within occupational health and safety, etc.

Throughout the programme students are placed in different multidisciplinary groups for different assignments. When applying theories and concepts in practical cases, the students thereby bring a mix of perspectives and professional experiences. This helps demonstrate the complexity of real situations and the need to develop a multifaceted view on Ergonomics as well as illustrate how different perspectives sometimes may be contradictory. The different backgrounds of the students contribute to broadening the students' knowledge and application areas. It is sometimes perceived provocative to the students (which is one point behind mixing them), but it opens up new perspectives and facilitates learning about systems thinking. With time the students express the importance of having all disciplines in their work groups. If one discipline is missing in group work (which sometimes occurs due to fewer students with a technical background), this is pointed out by the rest of the group.

The mix of students sometimes constitutes a pedagogical challenge for the teachers as well. The courses need to be adapted to handle students with different knowledge and background. Some course activities may seem challenging to some students while easier for others. At the same time there is a need to have a common platform in each subject from which to elaborate a common view on Ergonomics and HTO. This is handled by teaching the basics within each course very concentrated and leave individual studies to the students. Different assignments and group work also constitute important course activities for the student to go deeper into different knowledge areas within each course.

Another challenge with the mix of student is that the half-time students have a lower rate of finishing their thesis work. They also tend to need to take some time off from their studies during the first year and then return to their studies a few years later. The halftime students' lower examination frequency seems to be related to more complex life situations as parallel work and family situation. At the same time these students contribute much to the educational sessions because of their work life experience.

#### **4.3 Teachers with multidisciplinary backgrounds**

The master's programme is managed and continuously developed by three main teachers who have collaborated in the master's programme since 2007. Their competences and research areas cover complementary multidisciplinary areas such as mechanical engineering, physiological ergonomics, cognitive science, Ergonomics/Human Factors in general, work organization, group dynamics, and industrial management and engineering. The broad competences of the teachers cover the wide field of Ergonomics and contribute to the possibility to convey a systems perspective of Ergonomics. Two of the teachers also contribute a great deal in each other's courses, which facilitates overlapping of ideas and the teachers can serve as an interactive link between the courses. This facilitates for the students to see how the different courses are interconnected and how different areas influence other areas.

The teachers and guest lecturers hence represent disciplines of engineering, behavioural sciences and medicine. This facilitates the possibility to bring forward standpoints from different disciplines from a pedagogical point of view to illustrate how a phenomenon may be regarded from different perspectives. Some students have pointed out that they appreciate that the teachers express their sometimes different perspectives on a phenomenon, as this helps the students to develop a more fine-tuned systems perspective.

Having teachers with different disciplinary backgrounds also constitutes a challenge. It is important that the teachers have a basic common understanding of the whole programme and the role of each course and each teacher. This is especially challenging when new teachers start acting in the programme.

#### **4.4 Student views on systems thinking in the programme**

In the student's answers on the questionnaire, there was a common emphasis on the importance of having acquired a systems/holistic perspective in their current or future profession, which they perceived they lacked in their undergraduate education. This regards students with background in health science, behavioural science as well as technical science. The comments further emphasized the benefits of acquiring knowledge and insight on: a) the interaction between HTO components in development of products and operations processes, b) the importance of ensuring human needs (which was particularly commented from the technicians' perspective), c) how to create better and safer operations system, d) the need to broaden their skills because of the increased complexity of today working life, and e) increased competence to work across disciplinary boundaries. Some examples from students from the three different undergraduate backgrounds are presented below representing recently graduated as well as professionally experienced students:

##### *4.4.1 Comments from students with a technical background*

"From an engineering perspective I see an enormous advantage to be able to pay attention H, T and O in a system, to see that there is not any scapegoat in a problem. It is all about interaction." (Fresh undergraduate student attending the programme in 2012-2014)

"It is useful for technicians and engineers to broaden beyond the traditional technical. It contributes to safer and smarter technical solutions if you can add the HTO perspective. I have been actively working to introduce a HTO mind-set and also start a real work with HTO related tools at my workplace." (Student with 17 years professional experience attending the programme 2007-2009)

"I think it's very good that I have become better at seeing things in a larger perspective. Instead of just looking at the product itself and its design, you should also understand its context in order to ensure that the product being developed will be useful." (Fresh undergraduate student attending the programme in 2012-2014)

"I think it within all professional areas, but perhaps even more so in technology, requires a wider range of skills than what a three-year undergraduate education provides and also insights about the complexity of today's working life." (Student with 25 years professional experience attending the programme 2009-2010)

"The education gave depth knowledge that has contributed to increased confidence in working with health and safety issues from a holistic perspective." (Student with 25 years professional experience attending the programme 2007-2009)

##### *4.4.2 Comments from students with a health science background*

"[Aspects of the programme that I think is important to highlight for people with my undergraduate background are] increased systems perspective, increased depth of knowledge in all areas of Ergonomics, not only the traditional [Ergonomics]." (Student with 15 years professional experience as a physiotherapist attending the programme 2007-2009)

"You get a holistic view of HTO that is valuable. Very rewarding with the interdisciplinary backgrounds of the students. I've got a better view of my profession. I have not started work after education yet, but I believe that I have good opportunities for future work." (Student with one year general work life experience attending the programme 2012-2013)

“The focus on systems and holistic view has provided important insight on that work life, to meet human needs, promote development, productivity and health, are dependent on that particularly human, technology and organization are considered as symbiotic ergonomic concepts.” (Student with 25 years professional experience attending the programme 2009-2011)

“The programme has complemented my undergraduate education in a very good way. The HTO thinking gives us as occupational therapists much more and broader knowledge / ... / we have not had any HTO models to work from as the undergraduate education has focused the human being.” (Student with 13 years professional experience as occupational therapist attending the programme 2011-2013)

#### **4.4.3 Comments from students with a behavioural science background**

“I lacked the systems view before, the education provided me with better tools to analyse work situations, systems and security.” (Student with no experience within the professional domain before attending the programme 2007-2009)

“It is an extremely good education if you want to get a broad knowledge in an interdisciplinary field and learn multidisciplinary collaboration.” (Student with 11 years professional experience completing the programme in 2007)

“I have gained knowledge on how I can develop my skills and my thinking looking at various HTO issues based on my own background and I know it could be viewed from other occupational areas.” (Student with 31 years professional experience attending the programme 2011-2013)

“One of the most important things in this education was the broad competence both in teacher skills but also among the students / ... /. Everyone should undertake this education after 20 years work.” There is none of all university courses I have attended that even comes close to this programme. (Student with 45 years professional experience completing the programme in 2009)

## **5. Discussion**

This paper highlights examples and lessons learned of how to emphasize the interactive systems perspective in educational programme in Ergonomics. In this case, it is made through the development of a separate course (the HTO-course) and a developed interdisciplinary approach, which pervades the programme from selection of students, pedagogical structure of the programme and the teachers' multidisciplinary backgrounds. Although working with a full educational programme gives substantial room for manoeuvres, some experiences and ideas from this education may serve as inspiration in other human factors and Ergonomics educational contexts.

A basic idea in the programme is to have equal number of students with a technical, behavioural and health science background. There is, however, often less students with a technical background. It is important to include a clear technical perspective in the systems perspective of Ergonomics and not the least when highlighting the HTO-perspective. One reason for the lack of students with a technical background may be that they have not had courses touching the Ergonomics perspective in their undergraduate studies and therefore have a limited view on its application and how it relates to their own role as engineers. A previous paper focuses the benefits of the master's programme for engineering students separately (Karlton and Berglund, 2013).

There are advantages in having several teachers within the programme, such as different specialist competences and the possibility to highlight to the students how different areas within Ergonomics influence other areas. There are, however, also challenges in terms of how to develop and maintain a common view on the link between the different parts in the programme. This is especially challenging when the teachers have different scientific backgrounds and when new teachers are introduced in some programme activities.

In the design of the programme, there was a choice of what areas to include to represent Ergonomics. Having a large number of sub-disciplines add to a more multifaceted systems perspective on Ergonomics, but it also adds to higher complexity to grasp for the students. There is also a question of breadth in relation to possible depth to reach within each sub-discipline that is taught.

The need for a systems perspective is crucial to fulfil the aims of the programme. Promoting safety, health and wellbeing for the individual in parallel with operations performance can hardly be achieved without a systems perspective. The same applies for the aim that the students should be able to manage projects and change processes as well as cross-disciplinary collaboration. These different perspectives are recurrently highlighted in teaching as well as applied in the students' cross-disciplinary groups.

There is a challenge in that the students cannot identify with a profession after graduation, as the discipline is so broad and not clearly defined. They don't automatically become ergonomists and even if they would be, the students are unclear about what legitimacy they get in the job market. Students that already have a profession however don't experience this challenge to the same extent.

It emerges from the comments of all three student groups (health science, behavioural science as well as technical science) that the students experience a great value in the focus on a systems perspective in order to get better qualified for the complexity in today's working life. It is something they have lacked in their undergraduate education. Among students having a number of years professional work experience before attending the education this need is even more accentuated as they already have experienced the lack of knowledge and tools to handle system related aspects in their work. But also fresh students attending the education more or less direct after their undergraduate education realize the need for an ergonomics systems perspective. The broad competence in the teachers' skills as well as among the students is also highly appreciated as a means to help the students understand and apply a systems thinking.

## **6. Conclusions**

The Ergonomics and HTO master's programme is organized around a systems perspective, where the different HTO-components are studied separately but are linked by an explicit system course that runs like a thread through the entire programme tying together the different areas of Ergonomics. This approach has proved successful as a means to assist the students to discern how the interaction between system components forms the basis for a systems perspective. The systems view in the programme is consequently developed and conveyed through the organization of the programme, from the selection of courses and how these interlink to how it is emphasized by the examination forms.

The Ergonomics discipline in itself is nevertheless very complex and difficult to grasp for undergraduate students given a more and more specialized undergraduate education. While the multidisciplinary mix of students constitutes a pedagogical challenge it also provides a great potential in developing the students' understanding of the interdisciplinary overlapping and systems thinking characteristic to Ergonomics.

A major challenge within Ergonomics is the demand for breadth and depth in the various sub-disciplines, which requires a particular systems competence, discipline skills as well as a close co-working between teachers. This is an art to accomplish. In the master's programme presented in this paper the main teachers have long experience of working together in this respect. At the same time this creates vulnerability when a complementary or new main teacher needs to step in and supplement or replace an existing main teacher.

The need of Ergonomics as a systems discipline is constantly increasing in pace with increased globalization, organizational and technological complexity. This stresses the need for an understanding of phenomena that affect effectiveness, efficiency, satisfaction and other outcomes in production systems. The importance of a systems perspective in production systems development and sustainability should thereby not be underestimated. This suggests that training in systems perspective to a greater extent be included in various undergraduate educations. Students who are interested in specializing in a systems perspective then obtain improved conditions to specialize on this. The authors have recognized the need of an extended master's programme accentuated by comments from students who have completed the one-year master's programme in Ergonomics and HTO in KTH in Sweden. A development of the present programme into a deeper master's degree is now in progress.

It is the authors' hope that the lessons learned when emphasising and developing the interactive systems perspective within the master's programme presented in this paper would inspire to further development in Ergonomics education and practice.

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