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Education into the future – human factors courses with a systems perspective

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For ergonomics/human factors solutions to be beneficial for society and its members it is vital to apply a systems level perspective. Students who will be the future engineers, designers, and managers of socio-technical systems need to gain an understanding of how ergonomics/human factors can be integrated in the design of workplaces, organisations, products, and services. This paper gives examples of how the systems perspective is realised in courses on ergonomics/human factors at the Division of Ergonomics and Aerosol Technology (EAT) in the Faculty of Engineering at Lund University, Sweden. Examples are the application of theories and models of systems perspectives, guest lecturers from industry and other faculties, the use of supportive information technologies in teaching, arranging for student to visit and carry out projects in industrial settings, utilising peer assessment and written reflections to enhance learning, and communicating human factors research results. Strategies of the EAT educational environment that strengthen its teachers' pedagogical abilities are also presented.

Practitioner Summary: This paper describes examples of how the vital systems perspective can be realised in ergonomics/human factors courses. These include the application of theories and models of systems perspectives, guest lecturers from industry and other faculties, the use of supportive information technologies in teaching, arranging for students to visit and carry out projects in industrial settings, utilising peer assessment and written reflections to enhance learning, and communicating human factors research results.

Keywords: education, ergonomics, human factors, systems perspective, teaching

1. Introduction

It is vital to apply a systems level perspective in order to usefully address relevant ergonomics/human factors (E/HF) concerns (Wilson, 2014). For ergonomics/human factors solutions to be beneficial for society and its members, it is important to consider the solutions in a socio-technical system context and the environment of the system. According to the International Ergonomics Association, E/HF is defined as follows: "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance."

Wilson (2014) establishes that systems E/HF include six overlapping defining features: 1) a systems focus; 2) context – all behaviour and performance take place in a setting or context (often a complex socio-technical system) and the E/HF must be understood and accounted for in this context; 3) interactions – a system consists of interacting parts; 4) holism – a system should be seen as a whole where the cognitive, physical and social must be combined (concerning both E/HF inputs and outputs); 5) emergence – the recognition of the emergent properties of systems; and 6) embedding – the way E/HF fits in the organisational system and is embedded in practice.

The importance of knowledge about ergonomics/human factors and the application of a systems perspective are obvious in the education of engineering students who will be the future engineers, designers, and managers of socio-technical systems. In industry, a good engineer needs to have many skills, abilities, and competencies. Fundamental abilities are to think critically, to analyse problems, and to be creative. Students need to gain an understanding of how ergonomics/human factors can be integrated in the design of workplaces, organisations, products, and services. Courses in E/HF should reflect the multidisciplinarity of the field and, significantly, include a systems perspective. However, including a systems perspective in human factors courses is not straight forward and various types of learning processes need to be applied to develop students' problem solving abilities.

This paper presents and discusses the progressive teaching in ergonomics/human factors courses with a systems perspective offered at the Division of Ergonomics and Aerosol Technology (EAT) in the Faculty of Engineering at Lund University, Sweden. The paper describes the efforts taken in courses to enable the students to discover the importance of a systems perspective when applying human factors in real-life activities. The paper also presents strategies to strengthen the teachers' pedagogical abilities in the EAT educational setting.

2. Ergonomics/human factors research and courses at EAT

The teaching and research carried out at EAT focuses on knowledge about how people interact with, influence, and are influenced by their environment. This includes technological systems, other people with whom we cooperate (organisations), and our physical surroundings. The research findings are used in the design of products and environments that people come in contact with in their daily lives in the workplace, at home and in the community. EAT has three main areas of research: visualisation and interaction design; organisation and risk management; and indoor, outdoor and workplace environmental factors. In order to create a suitable environment for teachers, EAT is active in multidisciplinary research and research carried out in close contact or with stakeholders in the private and public sectors.

EAT offers some twenty courses annually. At the core are a number of undergraduate courses for students in the engineering and industrial design programmes in which they acquire fundamental knowledge about work environments and how humans interact with technological systems. A number of Master's level courses are also offered, intended for different Faculty of Engineering programmes related to EAT's areas of research. These include physical ergonomics, human-machine interaction, risk and safety management, and work organisation. EAT also offers courses for target groups outside of the Faculty, focusing on such areas as usability in computer interaction, human indoor environments, patient safety management, housing planning, and extreme thermal settings. Most courses include project assignments to be conducted in industries and other organisations and which emphasise the systems perspective. In some courses we use the Goal Equivalence Model (Akselsson, 1993; 2014; 2015) (see below) for discussing system aspects of interactions in a human-technology-organisation system and the interactions with its environment.

Students who want to pursue any of EAT's teaching and research areas in depth can receive supervision and write their Master's thesis at EAT.

As stated, EAT conducts up-to-date research on many aspects of the ergonomics/human factors area. The systems perspective is accomplished in collaboration between the researchers and the industry where the research is often performed, and where the results can be directly applied. In the close collaboration, in-depth E/HF research developments can be achieved, which serves as valuable input to the development of companies and their solutions for real-life human factors problems.

3. Examples of how the systems perspective is realised in EAT's E/HF courses

3.1 Application of theories and models of systems perspectives in the courses

Various theoretical models of ergonomic systems perspectives are presented and applied in EAT's courses and some examples will be presented here. In some courses we use the Goal Equivalence Model (GEM model) (Akselsson, 1993; 2014; 2015) for discussing system aspects on interactions in a man-technology-organisation system and interactions with its environment. The purpose of the model is to have employees and managers in an organisation reflect on the interplay between production (production quality) and working environment (working life quality) and to build up and support a common view – a systems perspective – between management and employers. Motivational factors such as commitment, knowledge and responsibility are linked to working life quality and constitute positive factors to bring about production quality. Negative factors such as difficulties in obtaining suitable personnel, high staff turnover, and sick leave are also linked to working life quality. Tools such as work organisation/leadership, learning culture, and man-technology interfaces affect both working life quality and production quality. The model presents the organisation as a system with feedback such that the organisation can steer towards a positive spiral of increased competitiveness and increased quality of working life.

Gaines and Moray's model (1985) of a hierarchical man-technology system is also used for discussing system aspects. Elements in the model are the technology, the individual, the team, the organisation of management, lawmakers, and the society and its culture. The model emphasises the importance of the higher sub-elements (the outer elements) for safety and health.

In EAT's courses specifically dealing with risk and safety management, Rasmussen's (1997) system perspective for controlling safety is studied in which the socio-technical perspective has an even broader impact. There is an awareness that a socio-technical system is divided into levels (legislative [national and international], regulatory, managerial, work planning and system operational) and that these levels need to have well-functioning coordination for safety. The system faces different sources of stress that can affect safety, such as the fast pace of technological change, increasingly aggressive and competitive environments, changing regulatory practices and public pressure (Rasmussen, 1997). If the system is to cope and adapt to these sources of stress, it is vital to have strong connections between the levels in the form of goal directedness with feedback, learning and action within and across levels. This will more effectively update the system, resulting in better an understanding of the characteristics of the system that can cause accidents and identification of the weak links when controlling the system's risk sources.

Another concept forwarded in some courses is resilience engineering, were resilience in a system is, as Hollnagel (2011) states, "The intrinsic ability of a system to adjust its functioning prior to, during or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (p. xxxvi). Resilience consists of four cornerstones, each representing an essential system ability according to Hollnagel: the ability to address the actual, to monitor the critical, to anticipate the potential, and to learn from the factual.

3.2 Guest lecturers from industry and other faculties

EAT often invites lecturers from industry and other faculties to participate in their courses. This enhances the credibility among students as the lecturer is an expert in his/her field and industrial setting. It also provides opportunities for presenting examples from reality and of the application of systems perspectives in real-life activities.

3.3 Supportive information technologies for increased learning

Supportive information technologies are used in the teaching to inspire and support the students in taking more responsibility for their learning. This does not simply mean enhancing the traditional model of teaching by using recording of lectures and letting the students work on their own. It is, instead, a new paradigm of teaching based on transparency, interaction and user-centred design of didactics and supportive technology. The new technology increases the students' opportunities to search and compile knowledge and to communicate by means of learning platforms. Students can acquire the basic knowledge base of a course on their own, which means that the teaching and learning situation in the classroom can concentrate on interaction and explaining more complex learning materials. The technologies facilitate this learning situation. By using video and voice calls through Skype, the students in the classroom or auditorium can communicate with experts in other countries resulting in in-depth discussions on ergonomics/human factors issues.

Several e-books and interactive educational material are available and have been developed as part of research projects where ergonomic aspects are visualised and simulated (Blomé, 2015; Blomé and Ek, 2014). The material is used in the undergraduate education. The Department of Design Sciences has also recently been involved in designing a national MOOC (Massive Open Online Course) in the research area of work environment technology in collaboration with several other universities.

It is absolutely necessary to make the most out of the new technology to meet the high expectations among new students, but also to consider the work situation of teachers and to enhance teaching without increasing the workload.

3.4 Arranging for students to visit and carry out projects in industrial settings

Critical thinking, the ability to analyse problems and use one's creativity are general criteria for students to become good engineers. McKeachie (1994) states that teaching need to focus less on communicating theories and facts to the students and more on developing the students' abilities to assess, collect facts, analyse and synthesise. These abilities are important when applying human factors in real-life activities.

Teachers need to provide a variety of teaching methods in order to capture differences in students' learning styles. These include lectures, laboratory lessons, field work, discussions, different text material.

Some of EAT's courses are intended to increase the students' understanding of how human, technological and organisational factors and the interaction of the three can affect human performance or the risk and safety in an organisation. The course topics do not often have simple or straightforward answers to questions like: How should a good safety management system be designed in an organisation facing risks? What is a user friendly human-machine interface?

The courses are thus well suited to have problem-solving components in the students' learning. We try to overcome the strategy of just transferring facts and theories about the subject to the students. In addition to lectures, the students carry out projects in small groups that include field studies in actual industrial companies. The courses are given in a later stage of the students' education (year three or four) under the assumption that they have matured and acquired a greater capability to work independently. A basic goal of the teaching is for the students to gain a greater and in-depth understanding of the E/HF subject by integrating theory and practice (empirics) and reach the higher levels of the Structure of the Observed Learning Outcome taxonomy (SOLO) (Biggs & Collis, 1982; Biggs & Tang, 2007).

Kolb (1984) states that, "Learning is the process whereby knowledge is created through the transformation of experience". In the current case, the students receive experience by visiting industry companies and performing small field studies. Experience-based learning has cognitive and motivating aspects (McKeachie, 1994). As teachers, we hope that the E/HF theories in the courses will become meaningful for the student when they understand that a theory may or may not be applicable in real life. We also hope that the field study experiences will generate questions in the students that will stimulate learning.

In the projects the students learn, for example, about risk management work in practice in a company and carry out a small study. The project is intended to structure the learning process of the course subjects and to get the students to match theory and practice but also to motivate them to read the course literature. Even if the field visits are short, we find it possible to relate them as a form of experience-based learning. The project and its results are presented in a written report and in a final oral presentation at a seminar. As the pedagogical research literature shows, discussions and lectures that capture experiences from field visits, as well as written reports and oral presentations are activities that promote learning from experiences. The project field visits highlight the importance of taking a systems perspective on E/HF.

3.5 Peer assessment to enhance the learning of human factors with systems perspective

The results of the student projects in industrial settings are applied in many of EAT's courses. We have introduced the pedagogics of peer assessment in the report writing procedure, where one student group evaluates and offers feedback on another group's report before it is completely finished. The aim to assist the student groups in their writing and more importantly, promote a discussion where course theory is coupled with practical human factors results. The course evaluations show that giving and receiving peer feedback on the reports as well as the discussions are most helpful in learning. The discussions should focus on: the design of the assessment methodology based on the E/HF question at issue in the project; the analysis of results related to theory; recommendations for improvements based on the project results; the industrial setting where the project was conducted; and challenges in general with an emphasis on the indispensable systems perspective.

Peer learning is defined by Boud et al, (1999) as, "The use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher". Central to this is that the students shall practice giving feedback on achieved tasks (Martin, 2008). The advantages of peer learning are that the interaction between the students creates mutual support and stimulation, and enables the use and learning of the language or terminology of a given subject. As a student, it is often about alternating between explaining something and listening and summing up.

Peer assessment can be seen as part of peer learning (Donaldson & Topping, 1996). Bostock (2001) presents a number of advantages of peer assessment as a method: It gives the student a feeling of owning the assessment process; improves motivation; encourages the student to take responsibility for his/her learning; mistakes made during the assessment are seen as possibilities for learning and not as a failure; it also encourages in-depth learning. Other authors state that during peer assessment the students learn to reflect and assess critically. Peer assessment requires the students to dig into the specific subject and gain a

deeper understanding of the subject by reading and evaluating another student's writing. Studies also show that peer assessments often are appreciated by the students.

3.6 Written reflections to enhance students' human factors thinking and reasoning

Teachers at EAT have also introduced the pedagogics of students writing short reflections on portions of the course literature to be handed in individually. The purpose of the reflections is not to answer specific questions, but to motivate the student to start thinking and reasoning about the literature they have read and possibly connecting it to the work and E/HF experiences from, for example, summer jobs workplaces. The reflections are sometimes published on the course's webpage where both the lecturer and students can access and read them. They also serve as input to seminars on ergonomic issues.

3.7 Communicating human factors research results in the courses

The E/HF research at EAT is conducted in many sectors and on various organisational levels. The research results are often well suited for use in the courses to exemplify the application of human factors knowledge as well as highlighting human factors problems in real-life activities.

In a course on risk and safety management, investigators' results from serious accidents and disasters that have occurred are also used to exemplify the systems perspective as a background factor in the causes leading to the accident.

4. The educational setting for teachers at EAT

This section presents some strategies of the educational environment to strengthen EAT's teachers' pedagogical abilities.

4.1 Teachers' pedagogical education

A majority of EAT's researchers, including professors and PhD students, participate in teaching in the undergraduate courses. A prioritised area in the Division's strategies is the teaching of undergraduate and Master's level courses. The strategy has short- and long-term goals for the teaching as well as action plans. Teachers are encouraged to actively participate in additional pedagogical education and training, and to take part in the Faculty's pedagogical conferences and seminars in order to learn new pedagogical tools. There is a long-term Faculty competence requirement that teachers complete ten weeks of formal pedagogical education.

The Faculty of Engineering invites its teachers to have their pedagogical merits assessed and in this way become members of the Faculty's Pedagogical Academy where they are given the title "Excellent Teaching Practitioner" and a salary increase. The departments in the Faculty where these teachers work also receive an increased allocation of funds.

Regular thematic seminars are conducted at the Department of Design Sciences to support cooperation and interaction between teachers. The Department also arranges annual educational inspiration days based on surveys of teachers' interests, experiences and current challenges. Examples of themes are e-learning, pedagogics, carrying out courses in practice, and cooperation between courses.

The didactic knowledge and experiences are shared freely among the teachers for direct use in or development of courses and the work climate among the teachers can be described as a strong educational one (Roxå, 2014). The front line activities and research on pedagogics has led to the establishment of the research area "Educational Development in Engineering Science" at the Department.

4.2 Teachers' education in their own subject area

The teachers are to actively participate in further education concerning their own subject. The Department supports and facilitates teachers who want to continue their education in postgraduate research studies. The Department can also offer economical support for participation in conferences for teachers who are unable to improve their qualifications in the framework of a research project.

4.3 Applying course experience questionnaires

The Course Experience Questionnaire (CEQ) is administered at the end of every course offered in the Faculty and is a means for promoting continuous improvement of courses and providing directions for future development. The students' opinions are collected using a questionnaire (web-based or paper-based). The questionnaire responses generate a report of students' opinions and open answers. The report serves as a basis for an evaluation meeting with students and the course director, where a plan for further improvements are proposed. A summary of the meeting and the students' general impressions of the course are then made available via the Lund University's website. The CEQ evaluations consist of measures relevant for a courses' pedagogical process and pedagogical development. A CEQ evaluation should be interpreted in the light of the examination statistics and the stated goals in the course syllabus. The CEQ constitutes an important component in the pedagogical quality work at the Faculty, together with the pedagogical education of its teachers.

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