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## A NOVEL APPROACH FOR UNDERGRADUATE RESEARCHER EDUCATION IN ENGINEERING STUDIES

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### Introduction

Entanglement of technological and social processes can be considered as one of the essential features of a modern information society. This means that the traditional engineering education and profession, which focused only on technology, face a challenge when adapting for a new environment. The securing of the competitiveness of the society's economy is typically accepted as a starting point for engineering education. However, values and expectations regarding the field of technology and higher education in engineering have changed during the last few years and, therefore, critical and ethical discussion about educational trends is needed when economical and humanistic viewpoints conflict.

Consideration of environmental values and ethical contemplation from a technological point of view can be seen as a necessity, in order to promote sustainable development in engineering education. Sustainable development in education is not only the knowledge relating to the environment, economics and society but it also emphasizes the learning skills, viewpoints and values of sustainable lifestyle and environmen-

**Abstract.** *The researcher education course for undergraduate engineering students has been developed in the Department of Process and Environmental Engineering at the University of Oulu. The course familiarizes students to research and researcher's work and aims to encourage them toward a research career. The approach of the course is unique in the field of engineering education in Finland. In this paper, the establishment of the course is discussed in the light changing targets and requirements of higher engineering education. Further, the course development from contact lecturing toward distance education is described. Finally, the possibility to use new and more versatile learning methods together with the traditional lecturing methods is considered based on the feedback given by the students.*

**Key words:** *researcher education course, undergraduate students, engineering, distance education, distance learning environment.*

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tally friendly living (UNESCO, 2005). Sustainable development in education can be promoted by an ethical and integrated approach, which considers the ecological, economic and socio-cultural dimensions objectively and in a balanced way. It can be achieved by educating teaching and research personnel, increasing interdisciplinarity of teaching and integrating it to the local circumstances. Furthermore, improvement of co-operation and networking, utilization of information technology based education methods and electronic dissemination of knowledge are also recommended (MINEDU, 2002; 2006a).

On the European level, engineering education is developed and diversified by the thematic network of Teaching and Research in Engineering in Europe (TREE). According to TREE, sustaining the current level of engineering education requires knowledge of information and communication technology, continuous professional progress and lifelong learning. Moreover, changing the university culture toward active learning, virtual university collaboration and continuous quality management in education and research is needed. (MINEDU, 2005; TREE, 2006)

In Finland, the attention of university education should focus on quality of education, e.g. the sufficiency of teaching and guidance resources, development of teaching and learning methods, and increasing the mobility of students and employees to maintain competitiveness of Finnish engineering education. Environmental issues and ethical considerations need also be emphasized and multidisciplinary of higher engineering education must be supported (Korhonen-Yrjänheikki & Allt, 2004; MINEDU, 2005; TEKES, 2006). From a pedagogical point of view, there is a trend in engineering education where the methods are changing from pure information transfer toward searching, utilization and evaluation of knowledge. In the future, teamwork, communication and problem solving skills, and information searching and processing skills will be highlighted in engineering education (Naukkari, 2006).

In addition to altered requirements and expectations of engineering education, the Bologna Declaration has brought about a huge renovation in European universities. The aim of the Bologna process is to equalize the university education systems and quality assessments used, and increase the freedom of movement of teachers, students and researchers in Europe. (Korhonen-Yrjänheikki & Allt, 2004; Lehtikoinen, 2005; MINEDU, 2006b). It has recently caused a change in the education practices of many European countries, e.g. in Finland the University Act (30.7.2004/715) and the Government decree on University degrees (19.8.2004/794) have been amended to meet the requirements and goals of the new two cycle system.

### **Education development at the Department of Process and Environmental Engineering**

The Department of Process and Environmental Engineering is one of the five Departments in the Faculty of Technology at the University of Oulu, consisting of Process Engineering and Environmental Engineering study programmes. Approximately 1000 students carry out their undergraduate studies in the Department. During the recent years, the main focus of education development has been on adapting the degrees and curricula to the two cycle system, and furthermore, on planning of the requirements, structure and methods of implementation of the compulsory Bachelor of Science in Engineering degree for the Department (Heikkinen, 2006; MINEDU, 2006b).

In the Department of Process and Environmental Engineering, attention has been paid to the quality of learning and teaching. The quality assurance system of the University of Oulu has been followed, and e.g. course feedback has been systematically collected and responded to, and an annual feedback day has been arranged (University of Oulu, 2006). Also subject know-how and the level of pedagogical education of the educational staff have improved during the last few years. As recognition, the Department of Process and Environmental Engineering has been evaluated as a Centre of Excellence in University Education in the years 2004-2006, 2007-2009 and in the years 2010-2012 by The Finnish Higher Education Evaluation Council (FINHEEC) (Parpala & Seppälä, 2003; Omar, 2006; FINHEEC, 2008). The current educational development project focuses on increasing target-oriented researcher education and developing it systematically. Related to the development



of researcher education, the Department of Process and Environmental Engineering has participated as a pilot department in the "Quality assessment and evaluation of the research work" project by the University of Oulu during the academic years of 2004-2005 (Kauppila, 2005). To improve the undergraduate students' research skills, the "Research Methodology: Student researcher's education" course for the undergraduate students has been given since 1995.

### The "Research methodology: Student researcher's education" course

The "Research methodology: Student researcher's education" course in the Department of Process and Environmental Engineering has been lectured since 1995. During the years the course has been developed from a traditional lecture course towards a distance learning course. The recent stage in the academic year 2006-2007 was performed in the Discendum Optima distance learning environment. Discendum Optima is a learning environment developed to support online studying and teaching. It can be employed:

- as a support for campus-based teaching and studying (e.g. for electronic distribution of course materials, saving and distributing students' course work, online interaction)
- as a Web-based environment for distance learning (e.g. during teacher training, student exchange or as a support for writing theses)

The course was developed and realized for the first time during the academic years of 1995-1997. The aims of the course are to introduce research work to the undergraduate students and to encourage them to become researchers. The objective of the course is to familiarise the students with a researcher's work description. The main themes of the course are how to start a research, how to carry out research work, how to fund projects and how to report the results (Keiski *et al.*, 2001; Melville & Goddard, 1996; Niiniluoto, 1999). In addition, ethical and moral issues are considered, such as the concepts of ethics and morality in general, research ethics and ethical malpractices in research work as well as the necessity of ethics in engineering education and in engineering work (Sundell, 1994). The development of the course has been done in close collaboration between students and teachers during the years.

In planning and development of the course, the changing aims and requirements in engineering education have been taken into account. In addition, several different teaching methods in accordance with constructivist pedagogy, such as lectures, seminars, student presentations, and discussions, as well as practical training in the laboratories, have been applied. The practical training period in the laboratories in the spring term is carried out under supervision of a senior researcher. During the training period the students have participated as laboratory assistants to the experimental and research work being done at the laboratory (Keiski *et al.*, 2000).

During the academic year 2003-2004 the course was lectured in a traditional way; in addition, at the same time an extra part (2 ECTS) was introduced via the Discendum Optima learning environment. The extra part focused on more detailed ethical matters, especially on professional ethics in research and engineering, emphasizing the consideration of ethical values and the importance of ethical matters as early as during undergraduate studies. The aim of the pilot project was to develop educational methods away from lecturing toward active learning. Furthermore, this development was implemented in order to offer a possibility to participate in the extra part to students who are already in working life by utilizing information and communication technology (ICT). The distance learning pilot project was arranged in co-operation with the Department of Process and Environmental Engineering and the Department of Educational Sciences and Teacher Education at the University of Oulu. In the pilot project, the students considered the given questions based on their own values and opinions and through interaction with the other students and teachers (cf. Vygotsky, 1982; Karjalainen, 2005). The course was assessed based on digital study diaries written by the students. The feedback was collected according to the quality assurance method of the University of Oulu (University of Oulu, 2006).

Based on the findings from the pilot project, distance learning seemed to be a suitable method



of researcher education for undergraduate engineering students. Generally, the feedback was encouraging and the students were quite excited about this type of a course. Also the results gained from the pilot project were encouraging and, therefore, the development of the distance course was continued. The results have been reported earlier (Jeronen *et al.*, 2004a; Jeronen *et al.*, 2004b).

After evaluation of the pilot project, the course was modified and given fully in the Discendum Optima learning environment during the academic year 2006-2007. In the distance learning course 12 students participated, out of whom eight completed the course. The course content was divided into five subtasks in which the students answered the given tasks related to a real research situation. In addition, all subtasks contained a study diary based on Silander and Koli (2003). The subtasks consisted of the following topics: choosing a research topic, planning the schedule, searching for information, writing a short literature survey, and in addition, consideration of ethical questions related to the selected topic. The students were given 1 to 3 weeks to solve each subtask. Besides distance learning, contact lectures in the beginning, middle, and at the end (3 in total), were given covering e.g. funding of research work. During the spring term, the training period in the laboratories was arranged as earlier.

The evaluation of the established course and the new approach that utilizes the distance learning has been done based on the feedback questionnaires responded by students. In this study, the main research question is to investigate whether students learn as well through distance learning environment, as when participating in contact lessons. The other research question is if the new different teaching, studying and learning methods contributes to student's learning and motivation.

The results were not processed statistically as the group of students is relatively small. However, the relevance of the gained information was ascertained by narrative deep analysis, by going the results through over and over again, and by comparing the conclusions with the original material (Jeronen *et al.*, 2004a; Jeronen *et al.*, 2004b).

## Results of Research

### *Findings from the distance learning course 2006-2007*

The students participating in the course during the academic year 2006-2007 were asked to write a study diary during the course, i.e. after completing each subtask they had to reflect what new ideas they had learnt. In addition, they reflected which factors helped in the learning situation and in understanding the task. At the end of the autumn period the students gave feedback about the entire part.

Based on the study diaries the students seemed to learn the core ideas of the given tasks. The students wrote that the course material, internet sources and lectures were helpful in performing the tasks. Some students wrote that completing the exercise helped in learning the course content. According to the study diaries, time required to perform each subtask was very variable, approximately half of the students reported spending more time than scheduled. However, the students saw that learning requires completing the tasks, and they were willing to follow through the exercises despite the extra time taken. Time management, in general, was mentioned as a drawback. Other difficulties reported in learning situations were uses of the distance learning environment and the library databases. A few students criticised also that some of the exercises were vague.

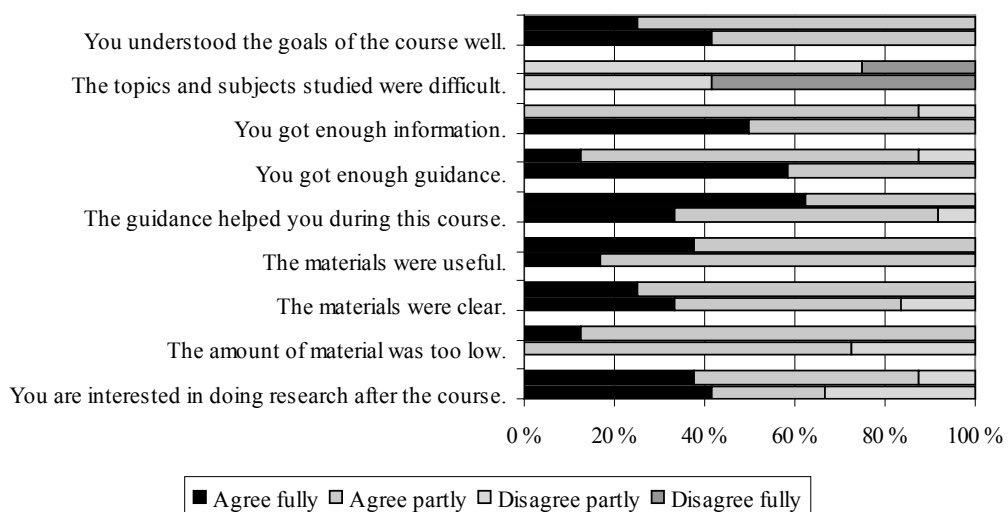
The students' feedback after the autumn period showed the students felt that research education, and applying the lessons to the real world in different situations, are useful. The students thought that the information given and the skills learned can be used in the "real world" such as in studies, profession, and even in daily life. Furthermore, the study of ethical issues in themselves was considered to be valuable, because ethics is typically integrated into the content of courses delivered by the Department. The students were satisfied that in addition to systematic research methods, they learnt data collection, reporting, and perseverance in research work. According to



the feedback, the students would have liked to have more information, study material and guidance. However, the guidance given on the course was reported to help learning.

#### *Comparisons between the distance learning course and the traditional lecture course*

In Figure 1, the feedback given about the Discendum Optima distance learning course (upper bars) as well as the traditional lecture course (lower bars) are presented. According to the feedback, the distance learning course was felt to be more demanding. The goals, topics and subjects of the course were understood rather well in both courses; however, in the distance learning course the understanding was noticed to be weaker. It is worth noting that the distance course consisted of given subtasks and exercises instead of traditional lectures. It can be clearly seen that guidance was requested more when the course was given as a distance learning course. The guidance given in distance learning was felt to be more helpful than the guidance during the lecture course. The delivered material seemed to be more useful and clearer in distance learning, but the amount of given information and material was said to be too low. Furthermore, according to the open responses, the students who took the distance learning course felt the lack of material as problematic. There was more interest toward research work on the distance learning course, which may be due to the use of an active study method.



**Figure 1. Feedback received from distance learning course (upper bars, n=8) and traditional lecture course (lower bars, n=12).**

#### **Discussion**

The study provided information on the applicability of novel teaching, studying and learning methods for research and researcher education. The teaching methods used in the Research methodology courses were compared. The courses were selected from the two different recent courses arranged. Active participation in the distance learning course was high, according to the students themselves. However, the students preferred to write short, concise answers instead of discussing or commenting on the tasks. In addition, the students were not willing to criticise, reflect or challenge the given material or the course content as a whole. This may be due to the teaching and learning culture in engineering education, which is still rather behaviouristic, and does not encourage students in reflection. The answers give a clear indication of the relatively poor readiness



of the students to reflect on and self-evaluate their learning. Consequently, the teachers need to give extensive guidance at the beginning of the distance learning course, and on the other hand, the students need to be willing to study new methods and ways to evaluate their own learning.

Distance learning courses are still quite rare in engineering education in Finland. Researcher education via a distance learning environment has not been previously reported in engineering education, although distance learning research courses have been arranged e.g. in the fields of medicine and pedagogy. For higher education also in engineering, according to our results a distance learning environment enables novel and more versatile learning methods, when used together with traditional lecturing methods. In this kind of education, the interaction between students and teachers is emphasized. This raises a requirement for especially the teachers to be familiar with distance learning methods, and willing to change their teaching towards active learning. Distance learning also demands more initiative and participation from the students when compared to traditional lecturing.

Practical experience from the research methodology distance learning course shows that engineering students typically consider discussion and peer critique as unnecessary. The findings support the results of a previous study by Naukkarinen (2006). According to Naukkarinen, engineering students and teachers see that the main benefits of distance learning environments or networks in engineering education are related to course management, material logistics and the use of new, more illustrative education methods, such as simulation and animations. According to our earlier studies, engineering students emphasise the importance of research and researcher education, and promotion of interdisciplinarity for improving and maintaining quality of higher education. They also think that raising the competitiveness of European higher education in general is important (Jeronen *et al.*, 2005). Therefore, it is expected that the combination of contact education and distance learning will give the best results in researcher education for undergraduate engineering students.

## Conclusions

The "Research Methodology: Student researcher's education" course has been a part of the study programmes in the Department of Process and Environmental Engineering for over ten years. The course has been continuously developed based on the feedback given by the students. In spite of the work already done, the systematic development of goal-oriented researcher education is one of the major development projects.

The course will be a valid element in the new two cycle system for studies fulfilling the requirements of researcher education for the Master's level set by the Bologna Process. To guarantee high quality of education, integration of research and teaching will be emphasised more intensively, and the goal for the future needs to be set to more closely relate the education to the research work done at the universities. Toward this end, the course can offer the answer. A lot of work in material and guidance development is needed to reach the goals, and furthermore, this will be a major challenge for teachers and advisors. By further developing the distance learning course and utilising it in researcher education, future experts can be educated. In addition, the course can act as a stepping stone for starting post-graduate studies, and for considering a research career as a possibility. At the Department, a new Research study module is being developed, and it will work as a link between the undergraduate and postgraduate studies, the "Research Methodology: Student researcher's education" course being a vital part of the module.



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