Human Factors Engineering: digital teaching tools and paper-free handouts for lecture notes

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Abstract: - In the current paper we share our dozen years of experience with digital teaching tools. We examine an integrated contact and E-learning course in the field of human factors for engineering students. We discuss the findings of research on student feedback from the Human Factors Engineering course with its didactics and proportion of E-learning. The research examined whether or not the employed E-learning and didactic methods were successful in the teaching process.

Key-Words: - E-learning, digital teaching tool, paper-free handouts for lecture notes, didactic methods

1 Introduction

1.1 E-learning

E-learning is used as an umbrella term to refer to computer-enhanced learning. It may include the use of web-based teaching materials and hypermedia in general, multimedia CD-ROMs or web sites, discussion boards, e-mailing, computer-aided assessments, simulations, games, etc., and possibly a combination of various methods. E-learning is education *via* the Internet, network, or standalone computer. E-learning can be defined as the transfer of skills and knowledge by using electronic applications and processes to learn as well as Web-based learning, computer-based learning, virtual classrooms and digital collaboration.

Especially in higher education, there is an increasing tendency towards employing E-learning - an explosive rate of growth, now about 25 per cent a year, has made E-learning one of the most popular and widely used learning methods in universities worldwide [1, 2, 3]. Universities are especially motivated to make use of new possibilities that modern technology has to offer. But some critics wonder whether online educators are doing enough to use all the possibilities for extending the classroom. E-learning often lacks creativity, they argue, saying it mostly consists of taped lectures being just posted online.

On the other hand, too often the focus has been purely on technology and not enough on variation of didactic methods in whole course combined with E-learning.

It is a common understanding [4, 5, 6] that the advantages of E-learning include flexibility and greater adaptability to the learner's needs. E-learning makes available multitude choices for student to find the personal and most effective style of learning. It is important for student to be aware of his learning style, know what his strengths and weaknesses are and are provided a variety of didactic methods to choose the most suitable ones; and the E-application can support the process [7]. On the other hand, the most often listed critical disadvantage of E-learning is the lack of human interaction, as the lecturer is cut out from the teaching process. Many researchers are in position that the university teaching staff has to dedicate more time to the communication possesses both when the communication is among the academics and when it refers to the communication with students [8]. New technologies are opening different ways for courses, seminars, discussion forums and other approaches to learning to be delivered online with innovative ways to communicate with lecturer and other students.

1.2 Lecture and E-lecture

A lecture is an oral presentation given by, for example, an academic that is aimed at teaching the students in a particular course. It has been maintained and also supported by prominent researchers [9, 10] that a didactic method such as lecturing is not the most effective teaching method. Though lectures are much criticized, universities have not yet found practical alternative teaching methods for the large majority of their courses. Lectures are used to convey critical information, history, background, theories and equations. Many authors have noted that the method of lecturing is justified if the objective is to present difficult to obtain or difficult to systematise material to large groups of students [12].

Critics point out that lecturing is mainly a method of one-way communication that does not involve significant audience participation. Therefore, Bligh argues [13] that lecturing "represents a conception of education in which teachers who know give knowledge to students who do not and are therefore supposed to have nothing worth contributing." Based on his review of numerous studies, he concludes that lecturing is not more effective or less effective than any other teaching method intended for disseminating information.

The E-lecture is a lecture delivered *via* electronic mail to networked individual computers. Usually, the lecturer stands in a room and gives information relevant to the lecture's content. In the case of an E-lecture, we remove the ordinary lecturing situation to the web environment, simulating a real “face-to-face” lecture as naturally and flexibly as possible.

1.3 Digital Teaching Tools

A digital teaching tool can be an interactive course module or an interactive portion of a course containing pictures, videos, animations or discussion boards. In our course, the digital teaching tool was a special unit of a specific topic and included E-lectures (video-based lectures); the slides used during the lectures and teaching materials for students were also added to the tool. In 2000, we decided that ‘digital teaching tool’ was an appropriate name for our creation because at this time it was a material object (CD-ROM) as well as a tool for digital or virtual teaching. At the time we could not use the Internet because it was too slow for transferring audio/video lectures to PC users and therefore we chose CD-ROMs. Since high-speed, broadband Internet connections have become the norm since 2003, all our digital teaching tools are available free of charge for all users *via* the Internet.

1.4 Common disadvantages of E-learning

In the very first years of this century we did not know much about the positive or negative outcomes of E-learning. There was already some expertise and the first attempts at introducing such teaching tools were made at several European universities, but there was no really serious research on the method itself. Moreover, there was not much knowledge about how to adapt pedagogical and especially didactic methods to E-learning, or expertise on the effectiveness of E-learning.

From the theoretical perspective, based on knowledge from research on human-computer interaction, we predict for several reasons that at least three negative aspects of E-learning can occur. First, E-learning as a teaching method is quite new and students do not have much experience in using it; it can create some confusion among students. Second, E-learning is impersonal and, in addition, it has the common shortcomings of a lecture, such as one-way communication with the student. However, human interaction can be encouraged and imitated by means of virtual, video-based digital teaching tools, and the result is no worse than a “face-to-face” lecture for a large audience where a single student is rather passive and communication with the lecturer occurs only as one-way communication. Third, we predict that students would have lower self-motivation. On the other hand, it is a common understanding that the advantages of E-learning include flexibility and greater adaptability to the learner's needs.

2 Human Factors Engineering

2.1 Course content

The course Human Factors Engineering (HFE) is an elective of 4.0 credit points according to the Educational Credit Transfer System (the ECTS). According to this European standard, the standard unit 1 ECTS is the equivalent of a 26-hour study load for the student.

The course content reflects engineering students’ need to improve their knowledge and skills in human factors as an important part of developing technology for the user. HFE is an applied field of psychology that focuses on the application of knowledge to the engineers. The general purpose of the E-learning course HFE is to meet the need for engineers and system designers and other professionals to understand how knowledge of human strengths and limitations, especially mental ones, can lead to better system design, more effective training of the user, and better assessment of the usability of a system. Moreover, this knowledge helps to apply the methods of task analysis and function allocation in human-machine systems and human-technological systems; understand human perception, cognition, attention, memory, emotions, and intelligence; understand the limits of human perceptual-motor capabilities, the limits of human cognitive functioning, and why people make errors; understand channels of processing and resource competition; and have a better understanding of workload and stress. The knowledge and methods needed to accomplish these goals are embodied in the study of human factors engineering.

In this particular HFE course a digital teaching tools was used as a particular unit of the subject, e.g. each digital teaching tool is covering a specific topic within the course. Each digital teaching tool includes E-lectures (video-based lectures); the slides used during the lectures; teaching materials; and a self-test for students. Printable handouts, paper-free handouts for lecture notes, and an MP3 audio version of the lecture were also included. Each unit of the digital teaching tools was a portion of the whole course.

Fig. 1 Digital teaching tool: 6th lecture Stress and Workload

All eight digital teaching tools of the HFE course are available *via* the Internet (http://www.tpi.ee/digiope/hfe/). Human Factors Engineering or Engineering Psychology is the discipline of applying what is known about human capabilities and limitations to the design of products, processes, systems, and work environments. Human Factors Engineering deals with the design of systems that people use at work and in leisure. It ensures that systems, jobs, products, interfaces, and environments are designed to match the physical and mental abilities and limitations of their intended users. Human Factors Engineering is a key factor in ensuring the effectiveness, safety, usability, acceptability, and success of human-machine system integration. It is therefore important for engineers to understand the capabilities and limitations of users such that systems are designed to enhance the performance and safety of the users.

Course content outline is as follows:

1st Lecture: Introduction - Human Factors Engineering or Engineering Psychology: Demand-resource theory in engineering psychology; Cognitive psychology; Stimulus and response; Cognitive theory; Engineering; Human factors science or human factors technology; Human factor; Human factors integration; Macro-ergonomics; Summary (http://www.enop.ee/tpi/digiope/hfe/hfe1.htm);

2nd Lecture: Mental Processes: Sensation: Sensory processing; Sensory thresholds; Vision; Hearing; Smell and taste; the body senses. Mental Processes: Perception: Organizing stimuli into patterns; a Rubin Vase; Pattern and object recognition; Filter theory; Person's perception and stereotypes; Law of constancy; Size constancy; Color constancy; Perception of time; Color vision; Müller-Lyer illusion; the visual cliff; illusions; Human capabilities and limitations: Capacity of perception; Visual sensory systems; the stimulus - light; Color sensation; Some variables that affect contrast and visibility; Contrast; Visual search and object detection; Bottom-up *versus* top-down processing; Target prediction inducing parallel search; Human factors implications for system designer (http://www.enop.ee/tpi/digiope/hfe/hfe2.htm);

3rd Lecture: Mental Processes: Attention: Classifications of attention; Non-volitional attention; The main reasons for non-volitional attention; Volitional attention; Overt attention; Covert attention; Executive attention; The qualities of attention: Focused attention; Sustained attention; Selective attention; Alternating attention; Divided attention; Attention span. Mental Processes: Memory: Classifications of memory; The three-stage memory model; Sensory memory; Short-term memory (STM); Long-term memory (LTM); Operative memory; Working memory; Levels of processing; Organization; Distinctiveness; Effort; Elaboration; Classification by information type: Declarative memory;

procedural memory; Topographic memory; Shape memory; Forgetting; Association; Serial position effect; Amnesia: clinical and psychological; Human factors implications for system designer (http://www.enop.ee/tpi/digiope/hfe/hfe3.htm);

4th Lecture: Mental Processes: Emotions: Emotion; Categorization of emotions; Cognitive theories of emotions; Scheme of emotional state; Emotional expressions; Computer-generated prototypes of facial expressions of emotions; Example of physiology of emotions; Perceptual theory of emotions; Affective events theory; Two-factor theory of emotions; Bipolar state of emotions; Asthenical emotions. Control theory. Locus of control. Mental Processes: Motivation: Intrinsic; Extrinsic; Homeostatic model of motivation; Incentive model of motivation; Motivation as a process; Theories of motivation; Maslow hierarchy of needs; The needs of employees; Choice theory; Ten Axioms of Choice Theory; Herzberg's two-factor theory; Need for Achievement (N-Ach); Intrinsic motivation and the 16 basic desires theory (http://www.enop.ee/tpi/digiope/hfe/hfe4.htm);

5th Lecture: Mental Processes: Thinking: Reasoning and formal logic base of thinking; Problem solving; Kepner-Tregoe technique; the principles of problem solving; Decision-making; Problem analysis versus decision-making; Rational, emotional, intuitive decision making; If-then plan; Rationalization; Mental Processes: Intelligence: Genetics and environmental component in intelligence; Genetics and IQ; Theories of intelligence; IQ - Intelligence Quotient; Examples of methods: Wechsler Adult Intelligence Scale (WAIS) and Raven's Standard Progressive Matrices; Estonian children's IQ research; IQ and population; IQ scores; IQ and gender; Emotional Intelligence (EI); Ability-based EI model; Mixed models of EI; Bar-On model of Emotional-Social Intelligence (ESI); Trait EI model; IQ and EQ; Practical Intelligence PI; Triarchic Model; IQ-EQ-PQ; Mensa International; Artificial intelligence - AI (http://www.enop.ee/tpi/digiope/hfe/hfe5.htm);

6th Lecture: Stress and Workload: Stress at work; Fight and flight reaction; Definition of work related stress; Stimulus-response stress reaction; Karasek's Model of Stress; CISMS Model of Stress; Estonian Occupational Stress Study; Organizational Health Framework; Psycho-Social Risk Factors Indicator (OHI-2); Coping with stress; Stages of stress and the first aid; Coping strategies: Goal-setting, Problem-solving, Correction of A-type behavior (workaholic), Internality, Personality balance, Social support, Work / life balance, Role conflict solving, Self-management: time management, personal financial resources management, emotional management, Self-esteem, Quality of life. Workload: Work overload and work underload; Demand – resource concept; Relation between workload imposed by task; Workload definition; Wickens' theory of workload; Occupational stressor for technology professionals; The classical model of workload: Load and capacity model; The effort-recovery model; Work demands; Work potential; Decision latitude; Negative aspects of workload (http://www.enop.ee/tpi/digiope/hfe/hfe6.htm);

7th Lecture: Human-Machine (Computer) Interaction**:** Human-machine model; Human-machine systems; Allocation of functions; Human-computer interaction; Human-computer interface; Human error; Human reliability; Categories of human error; Examples of human error; Human to human/group interaction; Communication; Perception of information; Information impartation; Common mistakes in communication; Communicational skills; Methods of official communication (http://www.enop.ee/tpi/digiope/hfe/hfe7.htm);

8th Lecture: Social factors: Social systems; Economic models; Social indicators; Three types of social factors; Relations between indicators; Collective memory; Macro-ergonomics; Red-line conflict; Groups and teams; Purposes and benefits of usage of teams; Team-building; Synergy; Team-building A, B, C; Teams' dynamics; Virtual teams; Toolsets for virtual workers; From learning to knowledge management; Knowledge location; Human and social factors in knowledge management; Pro the summary of HFE course (http://www.enop.ee/tpi/digiope/hfe/hfe8.htm).

2.2 Technical aspects

Each digital teaching tool consists of

(1) A video-based lecture (Flash Player - if someone does not have this software, the digital teaching tool automatically offers a version free of charge);
(2) The slides shown during the lecture (PDF format - the digital teaching tool automatically offers Acrobat Reader free of charge);

(3) Paper-free handouts for lecture notes (see Fig. 3);
(4) Some written material for student reading;
(5) Self-test for students;
(6) An MP3 audio-version of the lecture (MP3 format).

The system was built using PHP implementations for developing and running distributed architecture. We preferred PHP implementations for several reasons. First, they are platform-independent, e.g. it is a model of software that is independent of the specific technological platform used to implement it. Second, an advantage of PHP is that it is possible to get started with little or no cost. Third, video streaming is of little burden to the server. Fourth, it allows the necessary flexibility in usage of the digital teaching tools and developing them as a means of E-learning. Videos are streamed with PHP Streaming and played with the Flash Video Player by Jeroen Wijering. Both scripts can be downloaded for free for non-commercial use. The student texts are available in PDF format and students can download Adobe Acrobat Reader for free.

Utilising the opportunities available in Adobe Acrobat X, we created a folder of the instructor's slides in the paper-free lecture notes column. Adobe Acrobat X Reader, which students use to access the paper-free lecture notes, can be used for free. Handouts are an integral part of the teaching and learning system. The paper-free lecture notes we created are more than just a software solution. The student can use the handouts in two ways, based on personal preference: (1) print them out and then make their own notes, e.g. paper-pencil option, or (2) use the paper-free lecture notes option (Fig. 3).

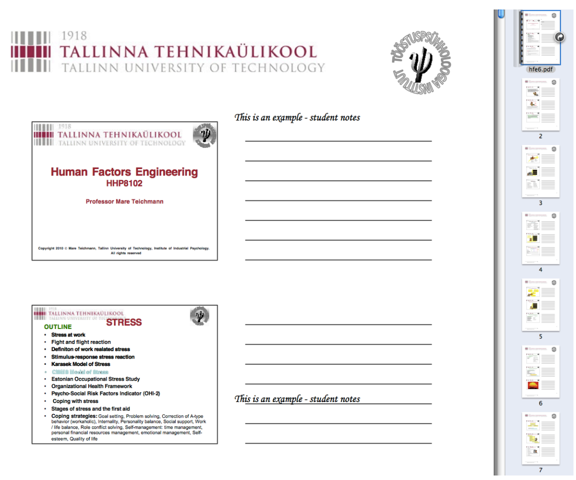

Fig. 2 Paper-free handouts for lecture notes: 6^{th} lecture Stress and Workload

In order to use the paper-free lecture notes option, the student must save the handouts (save as) on his own computer, and then he will be able to make notes in the right-hand column of the handouts. Paper-free lecture notes do not allow students to make notes on the teachers' handouts, only in the right-hand columns specifically meant for note-taking purposes. After the student is finished making notes, he must once again save his updated paper-free lecture notes.

If desired, the student may later print out the notes or gather all the materials from that unit into one folder and use them all for studying, whether on the computer screen or printed out on paper.

Self-tests after each lecture are integrated into digital teaching tools as self-assessment tools for students to evaluate their own knowledge on a particular topic. Self-tests consist of 8 – 10 questions, and the correct answers are included at the end of the test.

Computer demonstrations are integrated into the lectures in the digital teaching tools. For instance, there are various examples to illustrate human errors (Mars Climate Orbiter, Satellite Mishap blamed on human error, CD player in car).

Discussion meetings *via* Skype are a comparably new method being used. In this form of meeting, a group of students gather together virtually for educational purposes. Discussion topics are matched up to the topics of the lectures.

To minimize the negative effect of one-way communication between teacher and student in E-learning, i.e. to build up some two-way communication, different modern communication-technological options for coaching were adapted - coaching *via* Internet (e-mail) or coaching *via* Skype or "face-to- face" coaching.

Students' independent work outside the classroom is divided into three parts: student reading, individual or group assignments, and case study. Student reading, as the most traditional method of study, is still used in our course. There is a plethora of literature addressing the different issues of human factors. We listed two books as recommended reading:

(1) C.A. Phillips, *Human Factors Engineering*, 2005, USA: John Wiley & Sons Inc.
(2) C.D. Wickens, J.D. Lee, Y. Liu, S. Gordon-Baker. *Introduction to Human Factors Engineering,* 2^{nd} ed., 2004, Pearson Prentice Hall.

The purpose of case study is to maximize the critical thinking skills of students and teach them practical problem-solving in the field of human factors and decision-making. The task for students is to compose one case study from the everyday work practice of engineers and analyze the human factor component in that particular case, e.g. (1) to find a concrete case from engineering practice; (2) to describe the situation (What? When?); and (3) to analyze the described situation using and highlighting knowledge from the HFE course (Why?). This was an individual or group assignment.

2.3 Didactical aspects

It is acknowledged that educational objectives and passing along the content of the subject matter can be achieved in very different ways by using several didactic methods. There is a need to disseminate the best didactic methods in order to improve the general effectiveness and efficiency of training. Adequate didactic methods have great importance in training within any course, including our HFE course. Particularly important is that the didactic methods used confront the students with real challenges of engineering work. In our course, various didactic methods were used and integrated into the course in the classroom as well (Fig. 3).

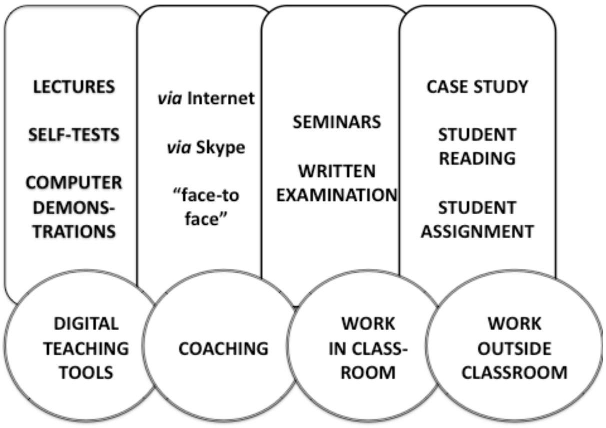

Fig. 3 Human Factors Engineering course design

The table below (Table 1) shows the didactic methods currently in use in the HFE course, structured according to the type of educational objective served. The plethora of different didactic methods was in use in HFE course. We choose the didactics very carefully. The main reason for employing so many didactic methods was to serve the students' different learning styles as well as to achieve the learning objectives and outcomes. Knowledge acquisition occurs primarily in E-lectures (video-based lectures) through the digital teaching tools, computer demonstrations, student reading, and student individual or group assignment. Feedback and questions *via* e-mail or *via* Skype, self-tests were designed to control (incl. control for own knowledge) and consolidate the knowledge. Discussion meeting *via* Skype or in the classroom, small group discussion, round table or panel meeting served the purpose of consolidation of knowledge. At the same time it was critical to teach students actively to use their knowledge. It happens quite often that students know the basic facts, concepts and theories but they are not able to transfer their knowledge into the everyday engineering practice. This is the critical step in learning process in general because there is not much profit from the knowledge that cannot be applied and used in practice.

Table 1 Didactic methods for knowledge and skills

Knowledge E-learning and student independent work outside the classroom	**Knowledge and skills** Work in classroom
Digital teaching tools for academic lectures	Introductory lecture
Computer demonstrations	Demonstrations
Self-test	Experiments, simulations, and communication exercises and video feedback
Case study	Case study analysis
Feedback and questions *via* e-mail or *via* Skype	Feedback and questions
Discussion meeting *via* Skype	Discussion meeting in the classroom
Student reading, student individual or group assignment	Small group discussion, round table or panel meeting
Written Examination *via* Internet	Written Examination

Case study and case study analysis fulfills the similar purpose. Students were responsible individually to find real-life case from engineering practice and to analyze this case in discussion group at classroom. Of course, all other students actively participate in the discussion; ask questions to clarify the situation and to specify the solutions offered by author of particular case.

Experiments, simulations, and communication exercises and video feedback were didactic methods for develop students' skills, and not only the skills, but also for increase the students' ability to self-analysis of their own behavior in different simulated communication-interaction situations (communication exercises and video feedback).

Our dozen years of experience with digital teaching tools clearly show that students adapt to video lectures much better if they have an opportunity to actually interact with the lecturer before the E-learning starts, i.e. they can be certain that the lecturer is a real person. For that reason we always have an introductory "face-to-face" lecture in a classroom with the same lecturer that recorded the lectures in the digital teaching tool.

The purpose of demonstrations in the classroom is to familiarize the students with various methods used in cognitive psychology. For instance: Wechsler Adult Intelligence Scale (Fig. 4), Raven's Standard Progressive Matrices.

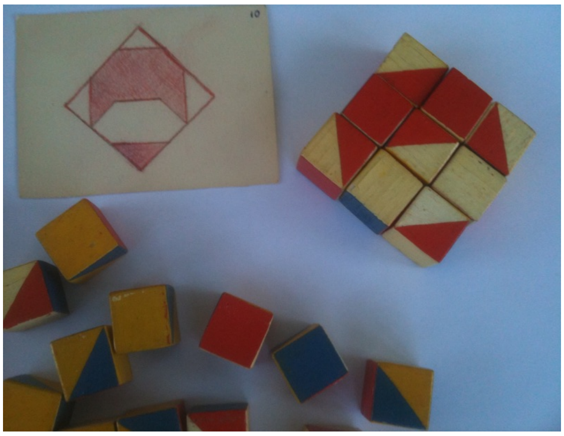

Fig. 4. Example of demonstration: a task from Wechsler Adult Intelligence Scale

Experiments, simulations, and communication exercises with video feedback have a critical place in students' individual skills training. For example: in order for the students to see that engaging simultaneously in two activities that require the same amount of attention can lead to making mistakes, a simple divided attention experiment is carried out; or in order to analyze one's communication skills, a communication exercise or simulation with video feedback analysis is done.

Case study analysis takes place in the classroom with the help of the most valid situations devised by students themselves. Students get a chance to analyze the human factor component and to find more practical solutions for problems.

Discussion meetings in the classroom, small group discussions, and round table or panel meetings are didactic methods that successfully help students learn to use knowledge in a particular field of study. We must point out that a discussion meeting *via* Skype can be just as lively and informative as a discussion meeting in a classroom.

Students were given two options for taking the written examination with multiple-choice questions: (1) take the exam *via* Internet or (2) take the exam in an auditorium using paper and pencil. In both cases, the time allowed for taking the exam is limited and the questions are equally difficult. Six versions of the exam of equal difficulty have been compiled. Each version consists of 33 tasks, including 4 tasks with multiple choices.

For example: Multiple Choices

Human Factors Engineering (HFE) or Engineering Psychology is the discipline of applying what is known about human capabilities and limitations to the design of

(1) Organizing, planning, leading, controlling;
(2) Products, processes, systems, work environments;
(3) Directing, goal setting, decision making, resource allocation.

In addition, 20 tasks had "True-False" choice options, for example:

Perception is a higher brain function about interpreting events and objects in the world

(1) True
(2) False

Questions in the exam asked students to name four examples (for example: give an example of self-motivation versus external stimuli), resolve four cases (for example: Case study - At the restaurant John smelled the aroma of some sweet cakes. This smell brings John's memory back to his grandmother's cakes from his childhood. What kind memory is it?).

3 Students' feedback and course evaluation

The Human Factors Engineering course is an elective or optional course for students from two faculties of Tallinn University of Technology – the Faculty of Chemical Engineering and Materials Technology and the Faculty of Mechanical Engineering. Three years ago the course Human Factors Engineering was an elective course in only one post-graduate curriculum, namely Industrial Engineering and Management. During the years that the HFE course has been available for engineering students, the popularity of course has increased dramatically; the course has become an elective (free-choice) in all of the curricula in the aforementioned two departments, and the number of students electing to enrol in the class has grown significantly year by year. In addition, students from the ERASMUS Programme (European Community Action Scheme for the Mobility of University Students) and students from other Estonian universities have started to enrol in the course, and students in other European Union member states (Spain, Portugal, Poland) as well as third countries (Turkey, Ghana, Brazil) have also expressed interest towards the opportunity to use virtual mobility in the context of the HFE course.

The use of technology may look very different in different courses. In our experience with digital teaching tools, we knew how crucial is to find the right proportion and balance between E-learning, students' independent work outside the classroom, and contact learning in seminars. Currently in use in the HFE course is the following opinion of proportion of integrating contact- and E-learning: 2 academic hours of "face-to-face" introductory lecture at university; 2 academic hours written examination; 16 academic hours E-learning with the help of digital teaching tools; 16 academic hours of seminars at university; 52 academic hours of individual student reading and individual work on papers (case study) with the benefits of traditional or virtual coaching (8 academic hours).

The results of students' studies in the HFE course are quite good: the average grade was 4.1; 3% did not pass the examination; and 12% got a score of "excellent".

A student feedback survey is carried out at the end of the course before the written examination. In the survey we use a Likert-type evaluation scale: 1 point: Very dissatisfied; 2 points: Somewhat satisfied; 3 points: Neither satisfied nor dissatisfied; 4 points: Somewhat dissatisfied; 5 points: Very satisfied. The feedback surveys show that the students' general satisfaction with the HFE course was almost homogenously high - 4.2 points on a 5-point scale. Similarly high was the evaluation of the digital teaching tools (4.2 points). Surprisingly, students' satisfaction was highest regarding seminars, i.e. work in the classroom (4.5 points). The lowest satisfaction was felt regarding the independent work outside the classroom (3.1 points).

When it comes to digital teaching tools, in their comments students stated that the primary advantage was ease of use, the opportunity to study wherever there is WiFi (for example in a dormitory or café or on a bus) and to manage one's time realistically. The highest scores were given to the opportunity to make paper-free lecture notes on the handouts we created, the MP3 audio versions of the lectures, and the slideshow using options. The lowest satisfaction was felt regarding printable handouts and self-tests (Fig. 5). E-lectures (video-based lectures) were evaluated even a little bit higher than the HFE course in general.

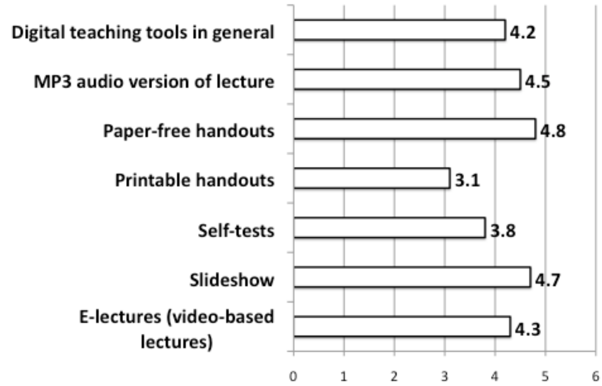

Fig. 5 Students' feedback survey: satisfaction with digital teaching tools

What was really intriguing in the student feedback surveys was finding that students evaluate differently their three options for coaching – *via* Skype, *via* Internet, and traditional "face-to-face" communication with a lecturer. The most favourable and highly evaluated was coaching *via* Skype (4.8 points), followed the coaching *via* Internet (4.2 points), and traditional "face-to-face" communication with a lecturer (4.0 points). A similar trend was seen in results evaluating the two options for discussion meetings – discussion meeting *via* Skype (4.7 points), and discussion meeting in the classroom (4.2 points). It should be pointed out that in general, the highest evaluation in the HFE course was students' satisfaction with seminars i.e. work in classroom (4.5 points).

Students have to choose between two options for the written examination – *via* Internet or in the classroom. Most of students (75%) prefer a traditional written examination in a classroom.

4 Result analysis

In our previous studies we failed to find any statistically significant evidence regarding the difference between the two types of lectures, i.e. E-lectures (video-based lectures) and classical academic lectures in the classroom. The analysis of the students' feedback suggests that engineering students generally have a highly positive attitude towards integrating contact- and E-learning in various courses. The findings of our previous studies indicate that successful E-learning takes place within a complex integrated system involving various didactical methods of teaching [10, 12, 14]. The HFE course was no exception.

The popularity of courses with digital teaching tools has increased from year to year among the students. However, we were very surprised to find that in the very first years that the option to choose either contact or E-learning was available, more than half of the students (57%) chose both options, i.e. they attended the "face-to-face" lectures and later watched the same E-lecture. Some students (24%) organised joint viewings of E-lectures in the campus dormitories. In the second year the number of students attending "face-to-face" lectures and watching the same E-lectures decreased to 12 per cent. When we asked about this irrational way behaviour they replied that it was interesting and they were not sure whether the E-lectures had the same content as "face-to-face" lectures [15]. This convinced us to make the digital teaching tools available only in the Internet and discontinue parallel "face-to-face" lectures on the above topics.

Focusing on the common disadvantages of the lecture as a didactic method, no additional negative influence from impersonal interaction with the academic was found in the case of the E-lecture. Moreover, the students claimed that they knew the academic from previous "face-to-face" lectures or from introductory lecture and thus the E-lectures caused no confusion.

The feeling of isolation experienced by students during E-learning is also often mentioned as a disadvantage of the E-lecture, although "face-to-face" lectures as well as other didactic methods such as discussion groups, round tables, panels, simulations and case studies in contact-learning seminars, and web-based communication can, in fact, help relieve this negative feeling and can often encourage students to attend "face-to-face" lectures and seminars. Identical feeling of isolation may arise in overcrowded classroom as well.

As to the students' lower self-motivation while using the E-learning option, combining and integrating E-lectures more with contact learning in the classroom, so that each seminar or practice requires the knowledge and material provided in E-lectures, can improve motivation. The principal failure of the lecture as a didactic method is one-way communication that does not involve significant audience participation. We tried to compensate for this failure by incorporating various participative learning methods into the E-lecture as well, such as rhetoric questions, self-test questions, and examples of engineering practice from everyday life that all require cogitating, analysing, etc. On the other hand, we also contribute a lot to the variety of didactic methods used in actual classroom seminars, i.e. demonstrations, experiments, simulations, and communication exercise with video feedback analysis, discussion meetings, small group discussions, round tables or panel meetings, and case study analysis. All these didactic methods are aimed to develop both the students' knowledge and skills. The aforementioned didactic methods help to better overcome the gap between theoretical knowledge and to use learned knowledge in practice and were appreciated highly by students.

We found it interesting that all *via* Skype options used by us was evaluated highly positively, i.e. discussion meetings and coaching. However, traditional discussion meetings in the classroom and traditional "face-to-face" coaching were evaluated lower than exactly the same didactic methods *via* Skype. This shows the popularity of Skype among engineering students as a comparably new technological possibility in teaching, rather than emphasizing disadvantages compared to both traditional didactic methods – "face-to-face" coaching and discussion meetings in the classroom. We are still in position that technology should be used in E-learning where it adds additional value for achievement the learning objectives and outcomes. Technology should not obscure the learning outcomes as the specification of what a student should learn as the result of supported study.

Contrary our expectations that the Internet option for final examination is preferred by students for the final examination the majority of students preferred the traditional classroom option for the written examination. We analysed students' academic efficiency as well as students' feedback on integrated contact and E-learning that employs various didactic methods. The results suggest that students generally display highly positive attitudes towards E-learning and active seminars in the classroom. Also, the students' academic achievement was good.

The students mentioned their better time management and the independence of their physical location (there is no need to sit in a university lecture hall to attend lectures) as positive characteristics of E-learning.

As suggested by our experience with HFE course, it is important to compensate E-learning disadvantages by using various technological and different didactic methods.

5 Conclusion

Regarding students' feedback there was found no difference between E-lecture i.e. video-based lecture and classical academic lecture. Our experience with digital teaching tools shows that the confusion among students is minimal if they have an opportunity to interact with the lecturer in real life before the E-learning starts.

Students' lower self-motivation by using E-learning options was found no convincing demonstration.

One most often mentioned critical disadvantage of E-learning is the lack of interaction and students' feeling of isolation. This deficiency must be taken seriously and compensate with various more traditional didactic methods used in classroom i.e. demonstrations, experiments, simulations, exercises, case studies, discussion meetings, round tables, and panel meetings etc.

We found that engineering students evaluated all *via* Skype options highly positively, even more positively than "face-to-face" coaching or discussion meetings in the classroom. This fact may indicate the popularity of Skype as relatively new communication method or the simulation of "face-to-face" communication is so good *via* Skype that it actually could supply the place of the real-life communication between student and lecturer. Additional research is needed and this could be an essential issue for future research.

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