TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

Asta Kybartaite

Impact of Modern Educational Technologies on Learning Outcomes

Application for e-Learning in Biomedical Engineering

Julkaisu 901 • Publication 901

Tampere 2010

Tampereen teknillinen yliopisto. Julkaisu 901
Tampere University of Technology. Publication 901

Asta Kybartaite

Impact of Modern Educational Technologies on Learning Outcomes

Application for e-Learning in Biomedical Engineering

Thesis for the degree of Doctor of Science in Technology to be presented with due permission for public examination and criticism in Rakennustalo Building, Auditorium RG202, at Tampere University of Technology, on the 11th of June 2010, at 12 noon.

Tampereen teknillinen yliopisto - Tampere University of Technology
Tampere 2010

ISBN 978-952-15-2385-4
ISSN 1459-2045

ABSTRACT

The arrival of new technologies, such as audio and video recordings, CD-ROMs, DVDs, personal computers (PCs) or iPods, is often followed by efforts to adapt them for educational purposes. Many Web 2.0 applications on the Internet such as wikis, blogs and podcasts have also been adapted for educational purposes by professional educators.

The research work for this thesis has been carried out in order to develop a virtual campus for Biomedical Engineering (BME). The work originated with the European Virtual Campus for Biomedical Engineering (EVICAB) project, which ran from January, 2006 to December, 2007. The aim of the project was to develop, build up and evaluate a sustainable, dynamic solution for virtual mobility and e-learning in the field of BME.

Video lectures for the virtual campus were recorded when lecturers presented them in a traditional classroom environment. The process of recording and publishing the video lectures was divided into five steps: 1) preparation, 2) recording, 3) editing, 4) producing, and 5) sharing. As an outcome, three types of data, i.e., video files, audio files and PowerPoint Presentations or PDF documents were synchronized in one application, in Flash format. Video file conversion software was used to produce the material in MP3, MPEG-4 and 3GP file formats for audio/video players and mobile phones. It thus became possible to access the files with free software, such as iTunes and QuickTime player, and then upload them to personal gadgets. The WordPress blog tool and publishing platform was implemented as an asynchronous communication system. As a result, virtual users have the possibility to leave their comments, messages and suggestions. A rating system was added so that the users could evaluate each lecture, which consists of several video recordings. Hypertext Markup language was applied so that all the materials can be presented as a web portal. Web code may be used as an open source so that everybody can contribute to it's development by downloading and editing it themselves. A coherent layout and color scheme have been selected so that the learning environment is as accessible and user-friendly as possible.

The above mentioned materials and methods were trialled when implementing an international course on Bioelectromagnetism (BEM) at Tampere and Helsinki Universities of Technology. Students with several different native languages attended the course. The course was offered both in a traditional classroom environment and in a virtual learning environment. A questionnaire was developed to collect the feedback from 66 students who participated in the course, in order to make a preliminary evaluation of the methods used. The questionnaire included 20 closed and opened-ended questions. Students had the opportunity to express their opinions by selecting one or more answers from multiple-choice questions and to comment in their own words. Several answers were graded on the Likert scale from 1 to 5; where 1 was for not useful and 5 was very useful.

An analysis of log-ins to the virtual campus was carried out in order to get information on when, where and how users accessed the portal, e.g., by PC, downloaded for an iPod or by media phone. This information has helped to improve the content and also proved that the virtual campus was accessible. The virtual users came from all over the world and they accessed the learning materials every day of the week with an average of over 40 visits per day. The video lectures for PCs were accessed the most, followed by those for iPods and media phones. Most of the users accessed the virtual materials with Firefox browsers using Windows operating systems. This information is important for further development as not every browser on every operating system is able to correctly decode the video files.

In order to estimate how e-learning has developed so far (during the years 2006-2009) among centres offering BME education in Europe, and to anticipate its future development, three questionnaires were administered, which have yielded valuable data about BME e-courses. It is anticipated that this information could provide the stimulus for planning future e-learning for BME and could also be useful in defining educational plans and goals.

A review of current teaching and learning theories and comparable practice in BME made it possible to compare the researchers' own experience and make improvements when developing the virtual campus. The constructivist theory, which was followed, emphasized the importance of making the virtual campus acceptable to students with different learning styles, e.g., for auditory, visual, tactile, kinesthetic, global, or analytical learners. One of the major advantages of e-learning is that it can make the learning and teaching process independent of time, place and pace. An initial evaluation of the results revealed that BME students and teachers are interested in the opportunities that e-learning can provide. It was possible to break traditional classroom boundaries and to develop open, low-cost, modern technology based virtual campus. This has thrown up new technical boundaries, which can be diminished through a considered analysis of the design and technology used. This research supports the idea that the main focus is on the learning content, which the educational technology serves to sustain. BME educators are in a position to develop and implement new learning systems that can take advantage of learning science, educational technologies and innovations in engineering education.

ACKNOWLEDGEMENTS

The work for this thesis commenced at the Ragnar Granit Institute, Department of Electrical Engineering, Tampere University of Technology. Due to departmental restructuring at Tampere University of Technology, the work was actually carried out and finalized at the Department of Biomedical Engineering, Faculty of Science and Environmental Engineering.

First of all, I wish to express my deepest gratitude to my supervisor, Professor Jaakko Malmivuo, PhD, who provided me with the opportunity to conduct research in his group and gave me his scientific guidance towards the completion of this thesis. I am indebted to the head of the department, Professor Jari Hyttinen, PhD, who guided my first steps in my career as a researcher. I would like to thank lecturer Juha Nousiainen, PhD, for his contribution to the early phase of the work.

I wish to thank the examiners of the thesis, Professor Jan Pawlowski, Dr, (University of Jyväskylä, Finland), Federica Vatta, Dr Eng, (University of Trieste, Italy), Professor Jiri Jan, Dr, (Brno University of Technology, Czech Republic) and Kai Pata, Dr, (Tallinn University, Estonia) for their valuable and constructive comments.

During the years 2006-2010 I had the pleasure of working with many great colleagues in an inspiring research environment. It was an honor to work with the partners on the EVICAB project. I would also like to express my appreciation to our secretary, Soile Lönnqvist, for handling many practical issues.

The financial support of Tampere University of Technology, Department of Biomedical Engineering, Ragnar Granit Foundation and International Graduate School in Biomedical Engineering and Medical Physics is gratefully acknowledged.

I wish to express my warmest thanks to my family. Despite geographical distance they were always there for me to offer support and encouragement. I dedicate this thesis to my mother, Nijole. Education has been always regarded as of primary importance in our family. I am grateful to my colleague and good friend, Katrina, for creating such a friendly working environment. I would also like to thank Lasse for support and understanding throughout this demanding period when I have been finalizing my thesis.

Tampere, May 2010

Asta Kybartaite

TABLE OF CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications, referred to in the text by Roman numerals I-XI.

Theoretical approach:

I. Malmivuo, J., Nousiainen, J., and Kybartaite, A. Biomedical engineering program on the Internet for worldwide use. In the *Proceedings of the 14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*, Riga, Latvia, 16.-20.6.2008, pp. 5-7.

II. Kybartaite, A., Nousiainen, J., Lindroos, K., and Malmivuo, J. Biomedical engineering and virtual education. In the *proceedings of Mediterranean Conference on Medical and Biological Engineering and Computing*, Ljubljana, Slovenia, 26.-30.6.2007, pp. 329-331.

Practical approach:

III. Kybartaite, A., Nousiainen, J., and Malmivuo, J. Technologies and methods for developing a virtual campus: application for biomedical engineering education. *Computer Applications in Engineering Education,* accepted for publication in the journal, 2010.

IV. Kybartaite, A., Nousiainen, J., and Malmivuo, J. Learning objects for the virtual campus of biomedical engineering. *IEEE Multidisciplinary Engineering Education Magazine (MEEM),* accepted for publication in the journal, 2010.

V. Kybartaite, A., Nousiainen, J., and Malmivuo J. Technology behind video lectures for biomedical engineering. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering, 2009*, Munich, Germany, 7.-12.9.2009, pp. 239-242.

VI. Malmivuo, J., Kybartaite, A., and Nousiainen, J. EVICAB – an open source portal for Internet education. Oral presentation in the World Congress on Medical Physics and Biomedical Engineering, 2009, 7.-12.9.2009, Munich, Germany, available at: *www.evicab.eu*, 2009

VII. Malmivuo, J., Kybartaite, A., and Nousiainen, J. EVICAB – biomedical engineering program on the Internet including video files for iPod. In the *Proceedings of the 4th European Conference of the International Federation for Medical and Biological Engineering*, Antwerp, Belgium, 23.-27.11.2008, pp. 2738-2741.

VIII. Lugmayr, A., Hornsby, A. Golebiowski, P., Jumisko-Pyykkö, S., Ubis, F., Reyman, S., Bruns, V., Kybartaite, A., Kauren, J., and Matthes, D. E=MC2+1: A fully digital, collaborative, high-definition (HD) production from scene to screen. *Computers in Entertainment (CIE)*, vol. 6, no. 2, NY, USA, The ACM Digital Library, p. 33, 2008.

IX. Kybartaite, A., Malmivuo, J., and Nousiainen, J. Developing media rich virtual learning material for biomedical engineering education. In the *Proceedings of the 14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*, Riga, Latvia, 16.-20.6.2008, pp. 421-424.

Evaluative approach:

X. Kybartaite, A., Nousiainen, J., and Malmivuo, J. Evaluation of students' attitudes toward virtual learning objects for biomedical engineering**.** *IEEE Multidisciplinary Engineering Education Magazine (MEEM)*, vol. 4, no. 4, pp.102-108, 2009.

Developmental approach:

XI. Kybartaite, A., Salerud, G., and Malmivuo, J. Developing practice of e-learning application in biomedical engineering in Europe. *The 3rd International* e*Learning Baltics, eLBa Science Conference*, accepted for publication in the Proceedings, 2010.

AUTHOR'S CONTRIBUTION

The research focused on four different aspects, i.e., theoretical, practical, evaluative and developmental.

The theoretical approach concerns learning theories supporting Internet education. Paper I introduces the idea of the European Virtual Campus for Biomedical Engineering, EVICAB and presents preliminary results and anticipated future developments and applications. Publication II briefly introduces the educational discipline of BME and considers the possibilities for transferring traditional classroom education to the virtual campus. The author wrote Publication II.

The practical approach deals with software and hardware implementations and virtual campus development. Manuscript III presents an overview of the technologies and methods used to create the virtual campus. Manuscript IV presents the learning objects of the virtual campus. Publication V analyses the importance of video in education and presents a method for the development of video lectures. Publication VI considers influence of the Internet for education, compares several Internet-based educational portals and describes how materials are organized within EVICAB. Publication VII considers why virtual education is suitable for the BME discipline, explains organizational issues within EVICAB, analyses the benefits for students, teachers and educational institutions and evaluates the possibility of transferring learning materials to portable devices, such as iPods and mobile phones. Publication VIII describes the process of creating, editing, and distributing video and is also an example of collaborative work. Publication IX considers the theoretical background behind video lectures and their advantages and disadvantages, analyses comparable examples of video lectures and presents some initial attempts at their development and evaluation. The author contributed to the development of the virtual campus, and particularly the video lectures, and also wrote Manuscripts III and IV, and Publications V and IX.

The evaluative approach aims to analyze students' and teachers' attitudes towards the virtual campus. Publication X considers methods for analyzing innovations in education, reviews similar initiatives and introduces evaluation based on students' feedback. The author contributed to the development of the questionnaire, analyzed and collected the data and wrote Publication X.

The developmental approach aims to analyze past experience and anticipate future trends in e-learning in BME. Publication XI analyzes how e-learning has been developing so far in the field of BME in Europe. Therefore, three questionnaires were prepared and sent to educational centres which offer BME. It was anticipated that the collected data could provide a stimulus for planning future e-learning for BME, and could also be useful in defining educational plans and goals. The author contributed to the development of the 2nd and 3rd questionnaire, analyzed data and wrote Publication XI.

LIST OF SUPPLEMENTARY PUBLICATIONS

This thesis is supported by the following reports related to the topic, referred to in the text by the Roman numerals XII-XIII. The reports are not attached to the thesis.

XII. Marozas, V., Jegelavicius, D., Kybartaite, A., and Nousiainen, J. Review of e-teaching/e-learning practices and technologies. EVICAB project report, available at: *www.evicab.eu*, 2006.

XIII. Marozas, V., Jurkonis, R., Kybartaite, A., and Nousiainen, J. Development and testing of e-learning and e-teaching practices. EVICAB project report, available at: *www.evicab.eu*, 2006.

The following supplementary publications, XIV-XV, are related to the Biomedical Engineering discipline, but are not included in this thesis.

XIV. Wendel, K., Väisänen, J., Kybartaite, A., Hyttinen, J., and Malmivuo J. The electric phenomena of multi-layered tissue in EEG sensitivity distributions. *Biomed Tech (Berl),* 2010.

XV. Kybartaite, A., Hannula, M., Narra, N., Arola, T., and Hyttinen, J. Construction of a highly realistic head/brain volume conductor model. *In the proceedings of International Conference Biomedical Engineering*, Kaunas, Lithuania, 26.-27.10.2006 pp. 294-299.

LIST OF ABREVIATIONS

AVI	Audio video interleave, file format
BEM	Bioelectromagnetism
BME	Biomedical engineering
BSc	Bachelor of Science, first cycle of educational qualification
CAMREC	Camtasia studio screen recording, file format
CD-ROM	Compact disc, contains data accessible but not writable
DVD	Digital versatile disk
E-	Electronic-
EVICAB	European Virtual Campus for Biomedical Engineering
FLV	Flash video, file format container
HTML	Hyper text markup language
ICT	Information communication technology
JPEG	Joint photographic experts group
M-	Mobile-
MP3	MPEG-1 audio layer 3
MP4	MPEG-4 video, file format
MPEG	Moving picture expert group
Moodle	Modular object oriented dynamic learning environment
MSc	Master of Science, second cycle of educational qualification
MySQL	My structured query language
PC	Personal computer
PDF	Portable document format
PHP	Hypertext preprocessor
PhD	Doctorate of Philosophy, third cycle of educational qualification
PPT	Microsoft PowerPoint
URL	Uniform resource locator
WMV	Windows media video
3GP	Multimedia container format defined by the Third Generation Partnership Project.

1. INTRODUCTION

Biomedical Engineering (BME) is multidisciplinary and is one of the fastest growing fields in science having significant impact on human health and well-being (LaPlaca et al. 2001). It is a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with biomedical sciences and clinical practice (Whitaker Foundation 2003). The broad nature of BME offers a number of challenges to all participants in its educational process (Harris et al. 2002), i.e., for:

- The students, who are encouraged to apply classical engineering concepts in profoundly new ways, relating them to living elements (Schreuders and Johnson 1999). Such students pursue university degrees or just in time information, are international, visiting or exchange students, ne(x)t generation students who mainly study outside the classroom, having work or family commitments, or who, due to health problems or disabilities, are not able to attend classroom lectures.
- Educators and faculties, which are compelled to keep up with all the advances in the related fields, to develop new learning curricula, environments and reasoning strategies anticipating the needs of prospective employers of graduates (Benkeser 2006), (Harris and Brophy 2005).
- Employers of graduates, who demand a wide range of capabilities (Benkeser 2006), (Linsenmeier 2003).

Educational programmes in the field of BME had their origins in the 1950s when several formalized training programmes were created (Benkeser 2006). By the year 2005, more than 200 universities of applied science, polytechnics, schools, academies and other institutions in Europe offered educational programmes in BME at all academic levels (BIOMEDEA 2005). Thus, many of the BME educational programmes are still under development (Nagel 2007). In general, engineering education has seen a massive transformation over the last few decades (Laurillard 2001), (Lee et al. 2001). The goals have changed from teaching facts to helping students to learn how to find relevant information, how to assess it, how to organize different and distributed information into an entity and how to engage in critical reflection and dialogue (Magennis and Farrell 2005), (Lechner 2001). Teaching and learning have moved towards more active (Prince 2004), student-centered (Lechner 2001), problem-based (LaPlaca et al. 2001), challenge-based (Harris and Brophy 2005), inquiry-based (Rocard et al. 2007), cooperative (DeZure 2000) and self-directed learning (Song and Hill 2007). The practice of using technology to deliver coursework has also created new opportunities for teaching and learning. For example, audio and video records (Chandrasekhar and Price 1989), CD-ROMs and DVDs (Eaton et al. 2008), personal computers (PCs) (Kulik and Kulik 1991), iPods (Palmer and Devitt 2007), Internet and Web 2.0 applications, i.e., wikis, blogs, podcasts (Boulos et al. 2006) have all been adapted for educational purposes. The evolution of educational technology has led to electronic (Cloete 2001), distance (Keegan 1994), network (Chan et al. 2001), portable (Williams and Fardon 2007), mobile (Duncan-Howell and Lee 2007), ubiquitous education (Hwang 2006), educational semantic web (Aroyo and Dicheva 2004) and intelligent education models (Guangzou et al. 2006) among others. Thus, nowadays the terms “e-learning” (Nagy 2005) or “virtual learning” (Anohina 2005) are commonly considered as umbrella terms describing any type of learning that depends on or is enhanced by the latest information communication technology (ICT).

It is possible to develop, implement, test and demonstrate the significance of educational theories, technologies and models through an open, free of charge, modern technology-based, high quality teaching and learning environment. An example of such an environment is the European Virtual Campus for Biomedical Engineering (EVICAB). It commenced on January 2006 as a two-year European Commission funded project. The objectives of the project were to develop, build up and evaluate sustainable, dynamic solutions for virtual mobility and e-learning in the field of biomedical engineering and medical physics (Malmivuo 2007). The solutions had to adhere to the Bologna Process (Benelux Bologna Secretariat 2009), i.e.:

i. mutually support the harmonization of European higher education programmes,
ii. improve the quality of and comparability between the programmes, and
iii. advance post-graduate studies, qualifications and certification.

The ideas and experience gained from this project were disseminated in international conferences (Malmivuo et al. 2008) and raised considerable interest in the future possibilities and applications of e-learning. This led to the extension of the study after the initial project was over, concentrating on the topic “Impact of Modern Educational Technologies on Learning Outcomes: Application for e-Learning in Biomedical Engineering”. The purpose of this further study was first, to make a theoretical evaluation of technology-enhanced education (theoretical approach), next, to develop a portal for e-learning (practical approach), then, to experimentally study how students accept e-learning (evaluative approach), and finally to predict future developments in the field (developmental approach).

2. STRUCTURE OF THE STUDY

2.1 PRECONDITIONS OF THE STUDY

The study was half theoretical, aiming to establish the general requirements for a virtual campus, and half experimental, aiming to define individual processes specific to the virtual BME campus. The following factors served as preconditions for the study:

- BME is a relatively new, multidisciplinary and interdisciplinary field.
- Educational programs in the field of BME are under the process of development all over the world.
- Not all universities, and especially newly established educational institutions in the field of BME are able to develop and provide up-to-date learning materials for students.
- Guidelines for the harmonization, accreditation and improvement of quality assurance are in the process of being established by the BIOMEDEA project.
- Internet and modern technologies are ever more commonly used in higher education.
- Educational theories can provide a foundation for Internet education, e-learning or virtual education.
- Globalization encourages students and educators to be more mobile. Virtual mobility is a relatively new concept.

- It is important to consider what are the 21st century skills that students need to succeed in their studies, work and life, and how modern technologies can support them.

2.2 OBJECTIVES OF THE STUDY

The research concentrates on four main objectives leading to conclusions:

1. Reviewing various learning technologies and theories.
2. Developing the virtual campus for BME.
3. Evaluating how students respond to e-learning and the virtual campus.
4. Analyzing the development process of e-learning.

The first objective is concerned with learning theories which support Internet education, e-learning or virtual education. The purpose is to theoretically define how to make a pedagogically sound virtual campus, which is acceptable to students, of high-quality and is based on modern technology. A literature review was carried out in order to define current best-practices.

The second objective deals with the development of a virtual campus for BME, which can be easily adapted to other disciplines, and the implementation of e-learning objectives using modern educational technologies and methods, i.e., software and hardware tools. Video lectures have been developed and tested as innovative learning objects.

The third objective used experimental methods to evaluate how technologies and methods for the virtual campus are accepted by students and educators. A student questionnaire was designed in order to collect quantitative and qualitative data for evaluation, and data from the website statistics' counter was analyzed.

The fourth objective concerns the development process of e-learning in general. An international survey has been prepared and sent to BME educational centers, and opinions from e-course developers and teachers have been gathered.

2.3 RESEARCH QUESTIONS

The primary objectives of the study were to come up with answers to the following questions and then to implement them and test their feasibility. This was only made possible through the development and implementation of the virtual BME campus. Certain research questions were mapped to achieve particular research objectives.

Research objectives:	Research questions:
1.	a) What cycle of qualification of BME education is needed for virtual education? b) What learning resources can be included in virtual education?
2.	c) What technologies and techniques can be applied and utilized in virtual education? d) What technical resources are needed for virtual education? e) What laboratory work could be implemented in virtual education, and how? f) How is it possible to provide instruction and tutoring in virtual education?
3.	g) How can students' examinations be organized and how can they test their knowledge themselves? h) What language could/should be used in virtual education? i) To what extent do BME students appreciate virtual education?
4.	j) How can institutions collaborate in order to get help and share information? k) What is the effect of a virtual campus at an international and cultural level?

The answers to these questions may help in the future development of e-learning for any discipline.

3. REVIEW OF THE LITERATURE AND THEORETICAL BACKGROUND

3.1 LEARNING SCIENCE

3.1.1 Review of learning theories

Educators consider learning as an active process leading to the acquisition of knowledge, which is long lasting, measurable, and specific to changes in behavior (OECD 2007). The main function of learning is to encourage the individual to become a problem solver and a critical and creative thinker. Learning also helps to develop an individual's self-awareness and awareness of his or her environment. The aim of teaching is to make learning possible. While the aim of teaching is simple, the activity of teaching is complex.

There are many theories aimed at supporting the learning and teaching process. For example, Paivio's Dual Coding Theory (1986) postulates that visual and verbal codes for representing information are used to organize incoming information into knowledge that can be acted upon, stored, and retrieved for subsequent use (Mayer 2005). Severin's Cue Summation Theory (1967) states that learning is increased as the number of available stimuli is increased. The stimuli supplied through different channels have to be relevant to each other or the distraction would cause a decrease rather than an increase in learning and retention (Kaur et al. 2005). The Atkinson-Shiffrin Model (1968) proposes a multi-store or multi-memory model for the structure of memory. It states that human memory is a sequence of three stages: (1) sensory memory, (2) short term memory, (3) long term memory (Mayer 2005). Baddeley's Theory of Working Memory suggests a model composed of three main components; the central executive, which acts as a supervisory system and controls the flow of information from and to its slave systems; the phonological loop, the visual-spatial sketchpad, and the episodic buffer. The slave systems are short-term storage systems dedicated to a content domain (i.e., verbal and visual-spatial) (Mayer 2005). Sweller's Cognitive Load Theory (1988) refers to the load on working memory during problem solving, thinking and reasoning (including perception, memory, language, etc) (Kaur et al. 2005). Wittrock's Generative Learning Theory (1989) recommends less reliance on a professor's lectures while simultaneously creating more self-reliance among students (Mayer 2005). Mayer's Theory of Active Learning (SOI) states that one potential of multimedia learning is that teachers can utilize the power of visual and verbal forms of expression in order to promote student understanding, Figure 1 (Mayer 2005). Gagner's Information Processing Theory stipulates that there are several different types, or levels, of learning. The significance of these classifications is that each different type requires different types of instruction. Gagne identified five major categories of learning: verbal information, intellectual skills, cognitive strategies, motor skills and attitudes. Different internal and external conditions are necessary for each type of learning (Kaur et al. 2005), (Mayer 2005). Constructivist theory states that: (1) knowledge is constructed, not transmitted, (2) prior knowledge impacts on the learning process, (3) initial understanding is local, not global and (4) building useful knowledge structures requires effortful and purposeful activity (Moore 2000). Cognitivist theory informs us that knowledge can be seen as schema or symbolic mental constructions, while the theory of behaviorism claims that learning is nothing more than the acquisition of new behavior (Moore 2000).

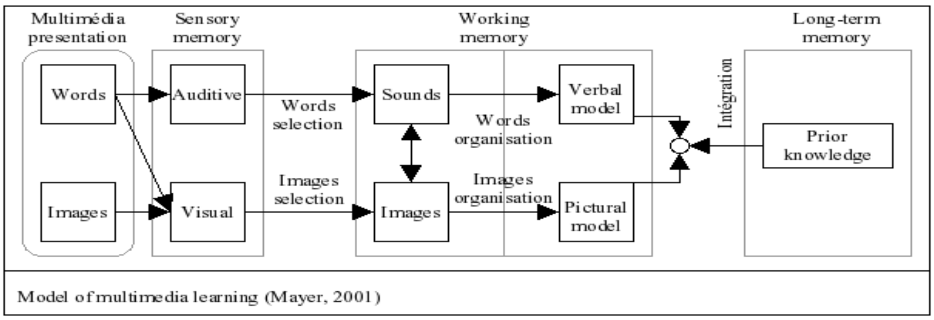


Figure 1. Mayer's selecting-organizing-integrating (SOI) theory of active learning. Adopted from Mayer 2005.

3.1.2 Learning process in terms of the human brain

The neuroscientific approach sees learning as the result of structural modifications within the brain when integrating all the perceived and processed information, Figure 2. This means that our brains are continually changing and developing throughout our lives. At the same time, our skills, knowledge and experience are also developing. Neuroscientists define learning on a biological level (OECD 2007).

The brain has two different sides or hemispheres, which are divided into lobes (i.e., occipital, parietal, temporal, and frontal). The lobes are responsible for different tasks: our language, reasoning, cognitive functions, emotions, intelligence, motivation, memory, etc (OECD 2007). Experimentation has shown that the hemispheres of the brain are responsible for different ways of reasoning (Martini and Bartholomew 2007), (Funderstanding, Neuroscience), i.e., the left side is responsible for logical, sequential, rational, analytical, objective thinking, whereas the right side is responsible for random, intuitive, holistic, synthesizing, subjective thinking. According to the reference (OECD 2007) “today, it is useful, even essential, for educators and anyone else concerned with education to gain an understanding of the scientific basis of the learning processes”.

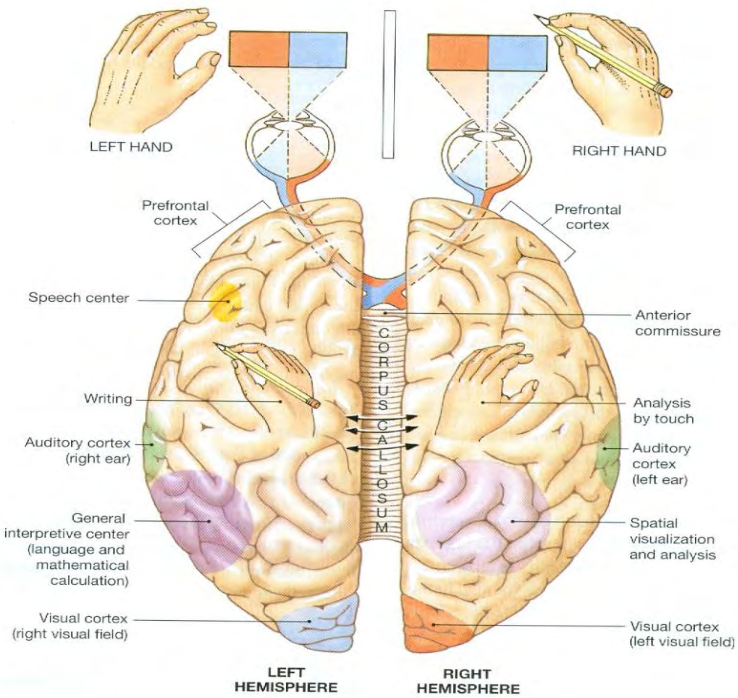


Figure 2. Hemispheric lateralization. Some differences between the left and right cerebral hemispheres. Adopted from Martini and Bartholomew 2007.

3.2 EDUCATIONAL TECHNOLOGY

3.2.1 Defining education technology

The concept of educational technology provides a fundamental theoretical basis for research and practice in teaching and learning. The field of educational technology is relatively new and has been struggling to establish it's boundaries (Luppicini 2005). According to the Association for Educational Communication and Technology (AECT, 2008) it is possible to define educational technology as "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Richey et al. 2008). When defining educational technology, it is necessary to distinguish between how engineers and social scientists use the term "technology". Engineers, technicians, and technologists view technology as a tool for material construction based on a systematic engineering knowledge of how to design artifacts. Social scientists view technology as a process for material construction based on the organization of knowledge for the achievement of practical purposes and also based on any tool or technique of doing or making by which capacity is extended (Luppicini 2005).

Luppicini (2005) defines educational technology as a goal oriented problem-solving approach utilizing tools, techniques, theories, and methods from multiple knowledge domains, to (1) design, develop, and evaluate, human and mechanical resources efficiently and effectively in order to facilitate and leverage all aspects of learning, and (2) guide change agency and transformation of educational systems and practices in order to contribute to influencing change in society. In general, it is possible to illustrate educational technology as a system, Figure 3.

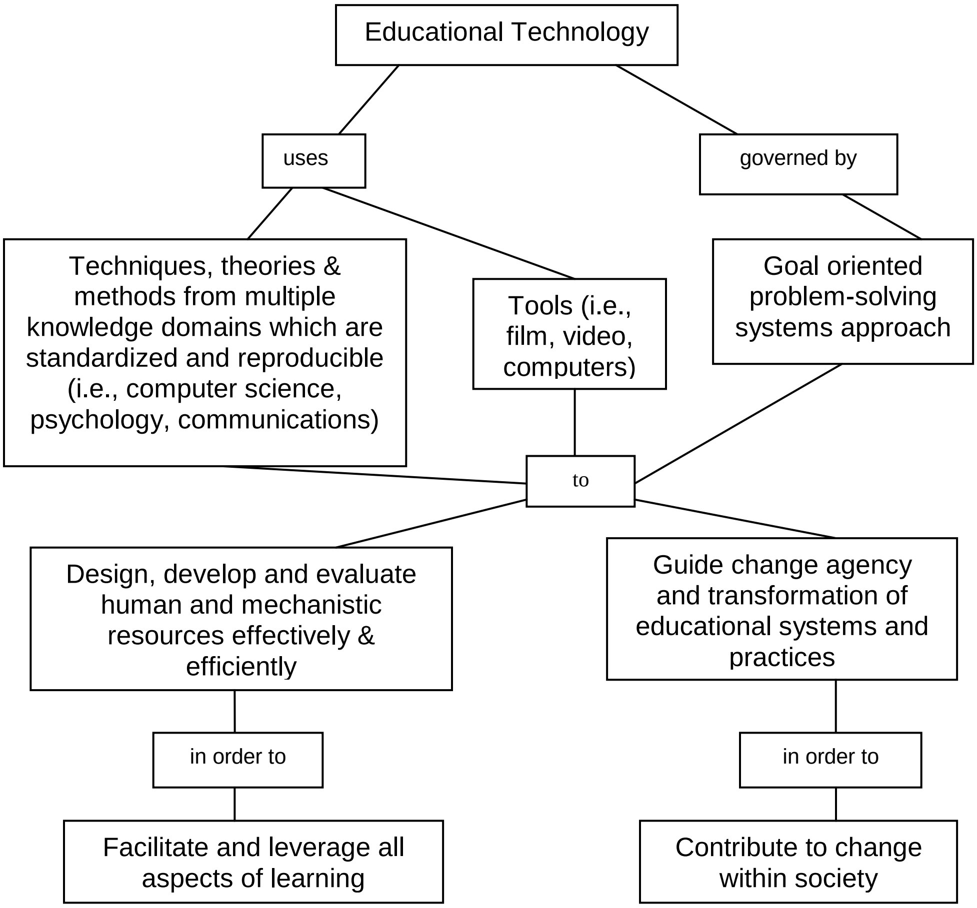


Figure 3. A systems definition of educational technology in society. Adapted from Luppicini 2005.

When writing this thesis, the main approach to educational technology was to consider it as a tool. The history of educational technology as a tool is marked with significant innovations. This list includes various hardware, e.g., portable storage devices, portable CDs, DVD players, calculators, notebook PCs, handheld PCs, pocket computers, personal digital assistants (PDAs), MP3 players, iPods, digital video cameras, and so on. In general, the advent of any new technology (i.e., software and hardware), especially in the field of entertainment, usually results in its being adopted for educational purposes, and universities are increasingly promoting the use of technology in the classroom (Palmer and Devitt 2007). Furthermore, the spread of the WWW, the Internet and other media, such as radio and TV, coupled with evolving social networking software and communication applications (e.g., Skype, Facebook, messenger and various forums, blogs, wikis) have precipitated an explosion in people's ability to communicate with each other and access information. A wide range of terms have appeared, which describe new types of education, e.g., resource-based learning, technology-based learning, distance education, electronic learning, mobile learning, i-learning, open learning, distributed learning, asynchronous learning, tele-learning, flexible learning, online education, web-based instruction, web-based training, teleconference-based education, ubiquitous learning, etc., (Anohina 2005), (Rogers 2000). Nowadays the term "virtual education" may be used as an umbrella term. According to a business dictionary, the term "virtual" means having most properties, the appearance, essence, or effect, of something without being that thing. The following features can be associated with virtual education: (1) a learning process is based on some technology partly or entirely replacing a human teacher, (2) a teacher and learner can be separated by time and place, but they are able to communicate freely, (3) a student can choose time, pace, place and amount of learning by him/ herself (Anohina 2005).

3.2.2 Instructional technology

Quite often, educational technology and instructional technology are regarded as synonyms. Thus, according to Association for Educational Communications and Technology (1994) instructional technology is the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning (Luppicini 2005). The best known instructional method is a lecture or traditional classroom learning. The lecture is a form of knowledge transfer in which the lecturer stands and talks in front of a roomful of people who listen, try to understand and write notes at the same time. The lecture originated from the days when printed material and copies of texts were not widely available. Nowadays, technologies allow us to copy, print, scan and digitally save materials and text with ease. Yet, traditional classroom lecturing is still one of the most common teaching methods in use today. Traditional lectures have several advantages:

- lectures allow one to socialize with people having the same interests,
- lecturers convey emotional involvement with the material, e.g., gestures, expressions,
- lectures allow direct communication, e.g., asking and answering questions.

However, among the many disadvantages are the facts that:

- there are usually too many people in the lectures,
- different people absorb different information at different rates,
- lectures usually involve the one-way delivery of information
- receiving information is difficult in real time because it is necessary to keep pace with the information as it is transmitted,

- usually, there is no time to understand things that are hard, and no time to explore the things that are interesting.

Electronic learning or e-learning has become a promising alternative to traditional classroom learning. It has also become one of the fastest moving trends in education (Zhang et al. 2004).
The advantages of e-learning include the facts that:

- it is a self paced, flexible, accessible, convenient learning process,
- it offers savings in cost and time (particularly for students),
- it is focused on learning through more active participation,
- it has easier content management, simpler data management and is easy to update,
- it offers the possibility of linking the content with other learning resources,
- it offers integrated assessment and testing facilities,
- it offers a variety of methods for measuring the learning success.

Among its disadvantages are the facts:

- e-learning cannot happen without supporting technologies,
- the technologies and tools are not always sufficiently reliable,
- there is a distance between the teacher and students.

In general, the term e-learning is not very precise and is used inconsistently. The most general definition (widely quoted without citation) states that e-learning is facilitated and supported through the use of ICT. Different authors define e-learning through different perspectives, i.e.,

a) the technologies,
b) the content
c) the instructional methods or process.

According to Zhang et al., (2004) e-learning can be defined as technology-based learning in which learning materials are delivered electronically to remote learners via computer networks. Clark (Connolly 2009, chap.8) describes e-learning as content and instructional methods delivered via a computer (whether on CD-ROM, the Internet, or an intranet), and designed to build knowledge and skills related to individual or organizational goals. The e-learning glossary suggests that e-learning covers a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms and digital collaborations.

3.2.3 Internet

The main element, which supports the evolution of current educational technology is the Internet. It has developed at an unprecedented speed over the last 20 years. The Internet started as a new, open system of information sharing between a few thousand scientists and evolved into a worldwide force for economic growth for billions of people. Due to the Internet's open protocols anyone can access useful information, create and share knowledge, send instant messages, make phone calls, etc. Thus, experts in the field claim that not all the possibilities for applications and service support have yet been realized with the Internet. Dial-up Internet access is a form of accessing the Internet via telephone lines. Such connections usually have latency as high as 400 ms or even more, which can make online gaming or video conferencing difficult, if not impossible. Broadband Internet access has been replacing dial-up connection in many parts of the world, offering increased speed (Golden et al. 2007). According to an EU Commission report (2010) Internet access and broadband Internet connections are growing year on year. Broadband Internet access is defined as access assuring an "always-on" service with speeds in excess of 144 kilobits per second (Kb/s). This speed is measured in download terms. The term broadband refers to high-speed Internet access, i.e., data transmission speeds exceeding 200 Kb/s, in at least one direction: down streaming (from the Internet to the user's computer) or up streaming (from the user's computer to the Internet) (Golden et al. 2007). A typical email consists of kilobits, music, several megabits and a film is several gigabits. In general, the broadband access currently is asymmetric, i.e., the bandwidth for downloads is far greater than for uploads. Broadband includes several high-speed transmission technologies such as digital subscriber line (DSL), cable modem, fiber (optical), wireless, satellite, broadband over power lines (BPL), and mobile, which could be called next generation access (NGA) technologies (Parliamentary Office of Science and Technology 2008).

3.2.4 Virtual campus

The Internet, and especially the World Wide Web (WWW), was one of the main reasons for the emergence of virtual campuses. The concept of the virtual campus is around 15 years old (Schreurs et al. 2009). No single definition exists but, in general, a virtual campus can be defined as an environment that uses the metaphor of a university (Fominykh et al. 2008). Usually a virtual campus is an open system for the design, deployment and evaluation of reusable learning materials. The term virtual campus is also often used to describe international cooperation among universities from several different countries (Bacsich et al. 2009).

3.3 EVALUATION OF EDUCATION

3.3.1 Questionnaires and surveys

Student feedback has been recognized as one of the most important factors in assessing teaching (Holmes and Brown 2000). This type of assessment is most often performed at the end of the course and frequently forms the basis for decisions about future improvements (Caulfield 2007). Constructively used feedback data can be beneficial for students in the form of an improved teaching and learning environment. It may also provide information for students when selecting course units or teachers.

Administrators may benefit through the more accurate representation of students' opinions in the decision making process (Aleamoni 1999). Student feedback is usually obtained by means of formal questionnaires. Other methods may be useful as well, e.g., casual comments made inside or outside the classroom, meetings of staff-student committees and student representation on institutional bodies. Nevertheless, questionnaires have two distinct advantages: 1) they provide the opportunity to obtain feedback from the entire student population, and 2) they document the experience of the whole student population in a more or less systematic way (Richardson 2005). The process of obtaining feedback by mean of questionnaires is relatively simple and convenient for both teachers and students; and has been accepted as a matter of routine in many institutions. For that very reason it may not always be taken seriously by those involved (Richardson 2005). Student feedback collected by means of questionnaires provides information about the students' characteristics and their distribution. Such a study is known as a descriptive survey and is usually concerned with what the distribution is, but not why the observed distribution exists. There are two major types of survey, cross-sectional and longitudinal. It is easier to define what type of survey is needed once the research objectives have been defined. The objectives should be sufficiently interesting and important to motivate individuals to respond. There are many different means of collecting data in a survey, e.g., 1) by directly administering the survey, 2) by mail, 3) by telephone (Internet-phone), 4) by interview, 5) by e-mail, 6) in web form and so on. Each of these means has advantages and disadvantages. The mode of interaction and the choice of technology influence the nature of the survey's questions and the processes used to answer them. The collected data should be processed into a useable format so it may be properly analyzed and interpreted in accordance with the aims and objectives of the study, and the findings should be presented in a way that others may easily understand.

3.3.2 Website statistics

In order to collect quantitative and qualitative data about learning materials that are on the virtual campus, the activities and actors can be defined. That procedure is known as visitor tracking (Barrett 2009), (Opentraker.net 2009). Technically, a visitor is any browser that accepts a "cookie". By this definition, a visitor is a human being and his/her actions are "human events" because only humans use browsers to navigate the Internet. If a "cookie" is not accepted, then the IP number can be used to track visitors. One visitor can make multiple visits to the site. A returning visitor is a visitor who revisits a site after a period of more than 24 hours. Most website statistic systems allow the retrieval of information about hits, files, sites, visits, pages or Kbytes. Hits represent the total number of requests made to the server during a given time period (month, day, hour etc). Files represent the total number of hits (requests) that actually resulted in something being sent back to the user. By looking at the difference between hits and files, it is possible to get a rough indication of repeat visitors, as the greater the difference between the two, the more people are requesting pages that they have already cached (have viewed already). Sites are the number of unique IP addresses/hostnames that made requests to the server. Many users can appear to come from a single site, and they can also appear to come from many IP addresses so it should be used simply as a rough estimate as to the number of visitors to a server. Visits occur when some remote site makes a request for a page on a server for the first time. If the site makes a request to the server, and the length of time since the last request is greater than the specified time-out period (the default is 30 minutes), a new visit is started and counted, and the sequence is repeated. Since only pages will trigger a visit, remotes sites that link to graphic and other non-page URLs will not be counted in the visit totals, reducing the number of false visits. Pages are those URLs that would be considered the actual page being requested, and not all of the individual items that make it up (like graphics and audio clips). A Kilobyte (KB) is 1024 bytes (8192 bits). It is used to show the amount of data that was transferred between the server and the remote machine, based on the data obtained from the server log.

3.3.3 Internal and external quality assurance

Questionnaires, surveys and website statistical data can be defined as measures for internal quality assurance. Measures for external quality assurance may be available from standardized guidelines, prepared by the international organizations.

In general, several relevant quality assurance systems have been created and are still being developed in Europe. For example, the Bologna Process (Benelux Bologna Secretariat 2009) introduces a three-cycle system and invites educators to consider how to make pedagogy more student-centered and that the study provided adequately addresses the needs of the students graduates. The European Association for Quality Assurance in Higher Education (ENQA Secretariat 2009) provides standards and guidelines for quality assurance for higher education. The ERASMUS programme (Education and Culture DG 2009) has brought mobility to a wide range of students from different countries and backgrounds. The widely used ECTS, learner-centered system for credit accumulation and transfer¸ allows students to gain recognition for what they have learned at home, abroad, in formal education, through self-study or through work experience (Education and Culture DG 2009). BIOMEDEA furnishes Criteria for the Accreditation of Biomedical Engineering Programs in Europe (BIOMEDEA Project 2005).

3.4 DEVELOPMENT OF E-LEARNING

Trends in e-learning are becoming very technology driven and are heavily dependent on ICT developments, including extended broadband access, wireless computing, and the coverage of digital devices (Nagy 2005).

E-learning is also developing in the field of BME and worldwide, i.e., across Europe (Caruana 2009), (Christofides et al. 2009), the countries of North and Central America (Stefanoyiannis et al. 2009), (Llanusa et al. 2009), Africa (Rae 2009), Australia (Mukhtar et al. 2009), Asia and Oceania (Suh 2009), (Krisanachinda et al. 2009), (Khambete 2009), (Mochimaru et al. 2009), (Shah and Hamid 2009), (Weng et al. 2009) and Middle East countries (Duhaini 2009). Based on the literature review, the main problems that most BME educators face are:

- lack of resources with respect to both qualified teachers and equipment available for teaching,
- quality assurance procedures to improve the quality of academic education and the accreditation process,
- standardized guidelines, lack of updated teaching and learning materials.

4. MATERIALS AND METHODS

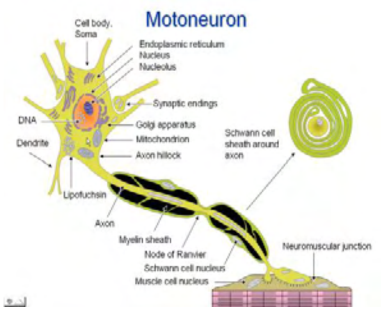
This thesis adopts four different approaches to the research: theoretical, practical, evaluative, and developmental. The theoretical approach is considered in Chapter 3. Practical, evaluative and developmental approaches are considered in Chapter 4. Sub-section 4.1 presents the methods for developing the virtual campus. Sub-section 4.2 presents the study about the evaluation of the virtual campus based on student feedback and web log-in statistics. Sub-section 4.3 presents the study about the development process in e-learning based on the international survey.

4.1 PRACTICAL APPROACH

4.1.1 Software and hardware tools

The practical approach deals with software and hardware tools for developing and implementing the virtual campus and its contents. Software tools include the Internet (e.g., broadband technologies), media players (e.g., Adobe Flash, iTunes, Quick Time), video and audio editing software (e.g., Camtasia Studio, Windows Movie Maker), software for converting different files (e.g., Movavi) and software for virtual communication (e.g., blog WordPress). Hardware tools include computers and laptops with different operating systems (e.g., Windows, MacOS), portable video and audio players (e.g., iPods, MP3 players) and media phones. These tools were all used when developing the virtual campus and are discussed in Manuscript III, Publications V and IX.

Lecture presentations, video and audio data were combined in one application when developing video lectures, Figure 4.



(a)

(b)

(c)

Figure 4. (a) is an example of a presentation slide (in Camrec format, 88,3 MB), (b) is a video (Windows Media Video File, duration over 16 min, bitrates 521 kb/s, dimensions 240x180, size 86,2 MB) and (c) is audio data used for developing the video lecture.

In order to include original presentation slides or documents, screen capturing technology was used to record a computer’s desktop activity. This required installing additional software on the computer. Camtasia Studio by TechSmith Corporation was selected. Screen captures were saved in .CAMREC files. Sometimes it was not possible to capture the screen and save it due to technical limitations and in such cases .PPT or .PDF documents were converted to graphic file formats, such as JPEG. Recordings were stored in digital video format on tapes, and either simultaneously or subsequently transferred to digital .AVI or .WMV file format using basic video creation and editing software, such as Windows Movie Maker. After initial editing, Camtasia Studio software was applied for synchronizing video and presentation slides. Primary, secondary and audio channels were adjusted as video, picture in picture (pip) and audio tracks, Figure 5. Lectures were segmented into time intervals based on the topics. When the lecture is too long and there are too many topics, it distracts a viewer and also the file sizes become too large. The markers for tracking certain slides were placed on a time line. The dimensions for video lectures were selected so that they could fit different computer screens without excessive scrolling or scaling of the content. We selected a very common .FLV file format for the video lectures. All the files were placed on the server so that the lectures are accessible via the Internet. The minimum bandwidth is 350 kilobits per second (Kb/s), but 1 Mb/s is recommended in order to watch lectures without buffering pauses.

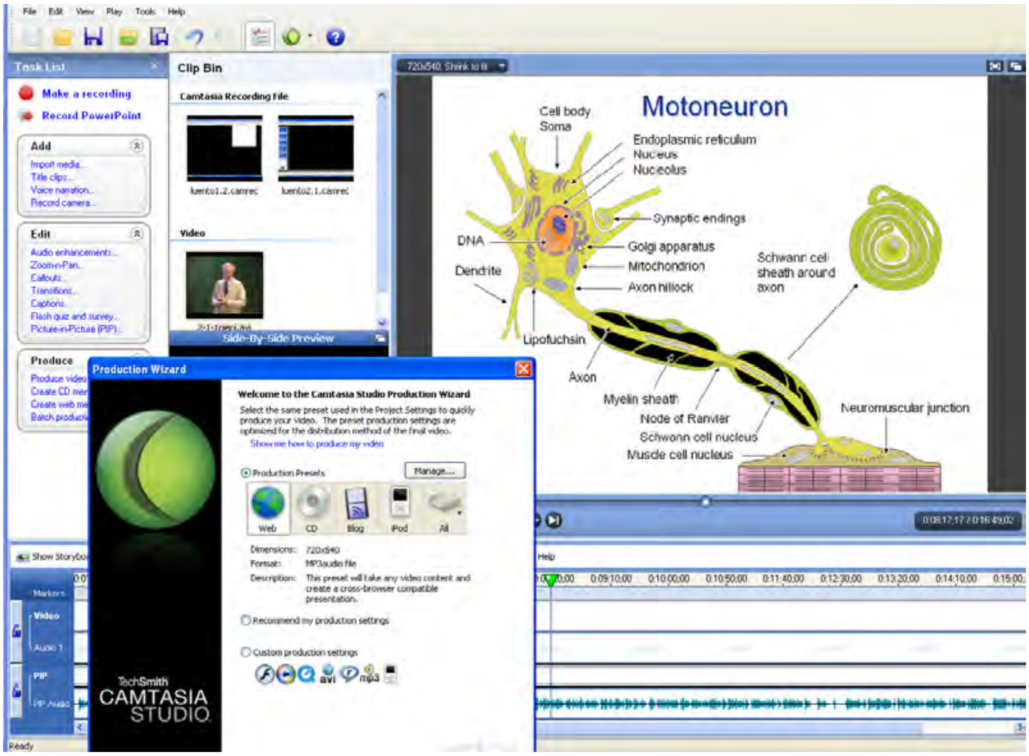


Figure 5. Editing window of a video lecture using Camtasia Studio software.

Commercial video file conversion software was used to obtain MP3, MP4 and 3GP files for audio, video players and mobile phones.

The WordPress blog tool and publishing platform was implemented as the asynchronous communication system and rating system. It is an open source project which, was downloaded and installed as a software script. For that purpose a web host was needed with a server, i.e., relational database managements system MySQL (version 4.0 or later), which supports and runs a widely used, general-purpose PHP scripting language (version 4.3 or later).

HTML was used to present all the materials on the website. Website code can be used as an open source, so anybody can contribute to its development. The layout and color schemes have been selected so that the accessibility and usability of the learning environment is as easy and user-friendly as possible. HTML can be executed on a PC under Windows or OS/2, on a Mac, or on a UNIX workstation. The website has been optimized for the Mozilla Firefox browser.

4.2 EVALUATIVE APPROACH

4.2.1 Questionnaire for students

When evaluating the virtual campus, the students' feedback was considered. The international course on Bioelectromagnetism (BEM) has been implemented at Tampere University of Technology (TUT), autumn 2007, 2008, 2009 and Helsinki University of Technology (HUT), spring 2009. Despite the different locations and time, the course content, teacher and requirements remained the same. The instructional materials used in the course were classroom lectures, exercises, video lectures, e-Books, and individual assignments. In addition, Internet examination was arranged. The digital material was available from the virtual campus, EVICAB. Students could make free choices individually as to whether to attend traditional classroom lectures or to follow them virtually as video lectures on the Internet, or both. Internet examination was compulsory for all students. The students' feedback was obtained by mean of a questionnaire, which utilized both closed and open-ended questions, so students had the possibility to express their opinions by selecting one or more answers from the multiple-choice questions and commenting in their own words. Some answers to the questions used the Likert scale grading system (from 1 to 5; where 1 = strongly disagree or not useful and 5 = strongly agree or very useful). The development of the questionnaire involved 4 phases.

- Phase 1: A pilot version of the questionnaire with 12 questions and the possibility for open comments was constructed and pre-tested by collecting data from 18 students, TUT, Autumn, 2007.
- Phase 2: A second version of the questionnaire with 20 questions and the possibility for open comments was constructed after revising the results of the first phase. Data was collected from 12 students, TUT, autumn, 2008.
- Phase 3: The second version of the questionnaire was administered and data collected from 25 students, HUT, spring, 2009.
- Phase 4: The second version of the questionnaire was administered and data collected from 11 students, TUT, autumn, 2009.

The results from all phases were combined to form a longitudinal study.

4.2.2 System for analyzing virtual participations

The web log-ins counting system was implemented in the virtual campus for internal quality assurance. The system operated according to the principle illustrated in Figure 6.

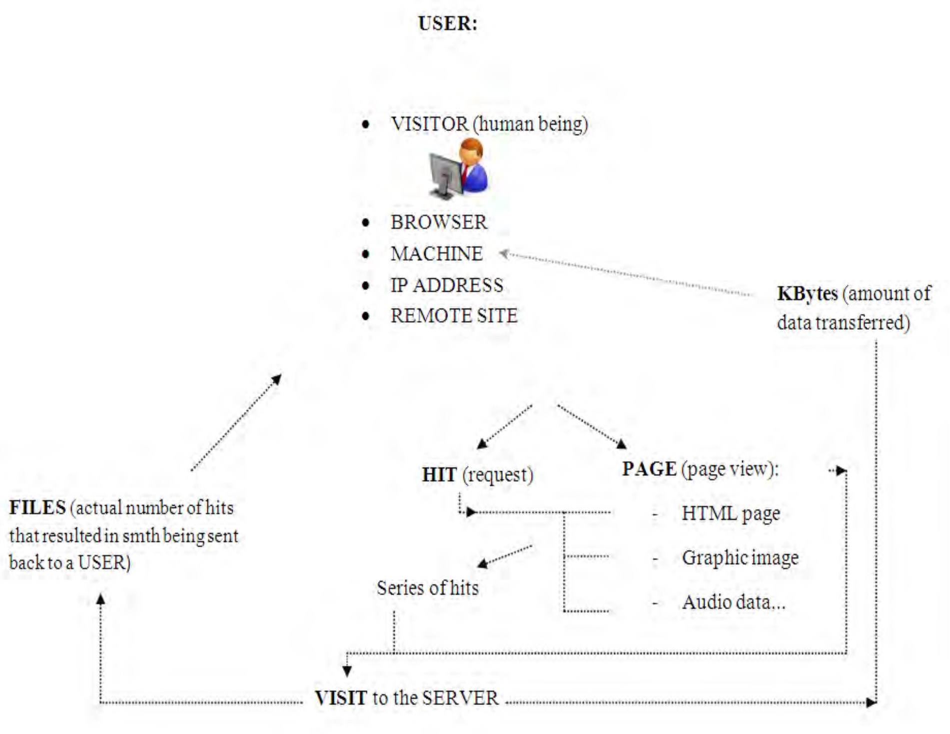


Figure 6. The generalized principle of the web log-ins counting system.

4.3 DEVELOPMENT PROCESS

4.3.1 International survey

The process of development of e-learning in BME in Europe was analyzed by preparing, administering and analyzing 3 surveys.

- Survey 1: two versions of a questionnaire about existing and planned BME distance courses were distributed. The extended version, which had 23 questions, was answered by EVICAB members and a shorter one, which had 16 questions, was used for other BME educational centers. The questionnaires were prepared and sent out to a total of 263 persons in September, 2006. The survey was divided into sections dealing with:
    - practical issues (information about, for example, course duration, workload, operative language, topic and cycle according to BIOMEDEA and the Dublin descriptors respectively),
    - internal and external quality assurance,
    - student mobility, lifelong learning and transparency,
    - other issues (pedagogical approaches).

- Survey 2: five questions concerning the use and recognition of current or planned EVICAB material and resources was prepared and sent out to the same respondents, January, 2008.
- Survey 3: a questionnaire with 30 questions combining survey 1 and survey 2 in order to compare results and define trends was prepared and sent out to the respondents, December, 2009 – January, 2010.

5. RESULTS

5.1 PRACTICAL PART

5.1.1 Virtual campus for BME

The virtual campus for BME has been developed and implemented on the Internet. The basic structure of the virtual campus is illustrated in Figure 7.

All the courses within the campus provide general information for students and either have e-books, or provide information and links about relevant literature. All the courses provide video lectures, and there are about 250 of these altogether. A number of the courses (25 percent) provide audio lectures, of which there are more than 80 altogether and there are over 160 iPod lectures which are offered on the majority of the courses (75 percent). In addition, about 25 percent of the courses provide phone lectures, of which there are over 100 altogether. About 25 percent of the courses include lecture slides or notes and about 50 percent include exercises. All the courses can be completed with an Internet exam, although only 1 course has been thus completed so far.

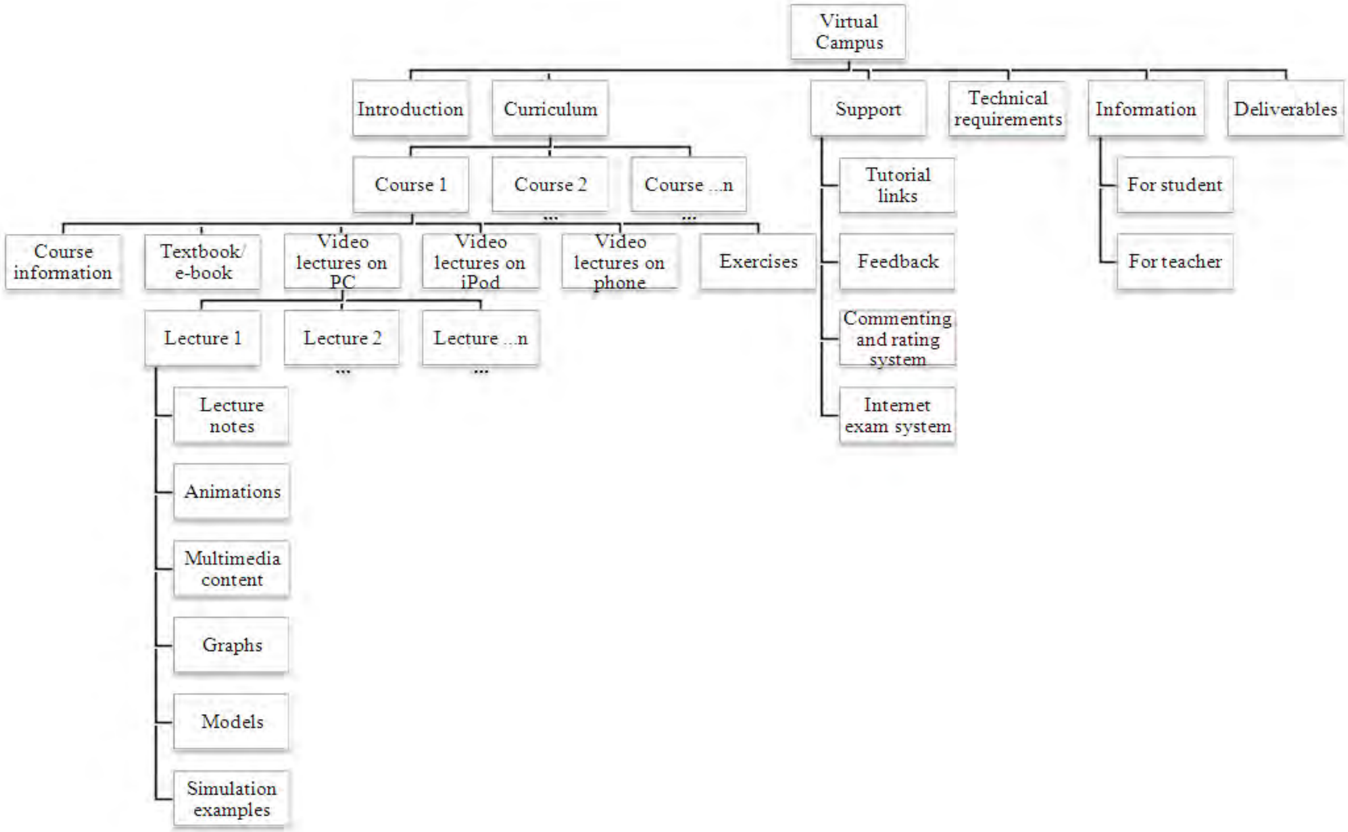


Figure 7. Generalized structure of the virtual campus.

5.1.2 Learning objects in virtual campus

Learning objects have been developed and implemented in the virtual campus, the nature of which is discussed in Manuscript IV. E-learning consists of interaction between a number of components, such as courses, assessments, teaching materials, study materials etc. These components have different characteristics. Therefore, they have been grouped into 5 levels as shown in Figure 8. These levels have been designed to correspond with those of traditional learning.

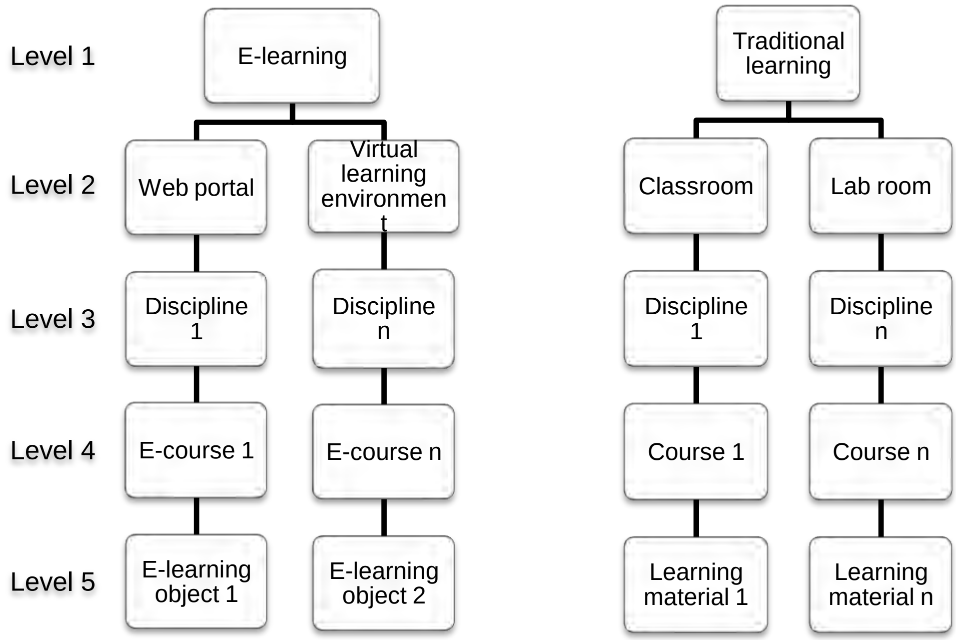


Figure 8. Learning objects.

5.1.3 Video lectures

One of the main learning objects is the video lecture. Figure 9 illustrates video lectures accessible through different modalities.

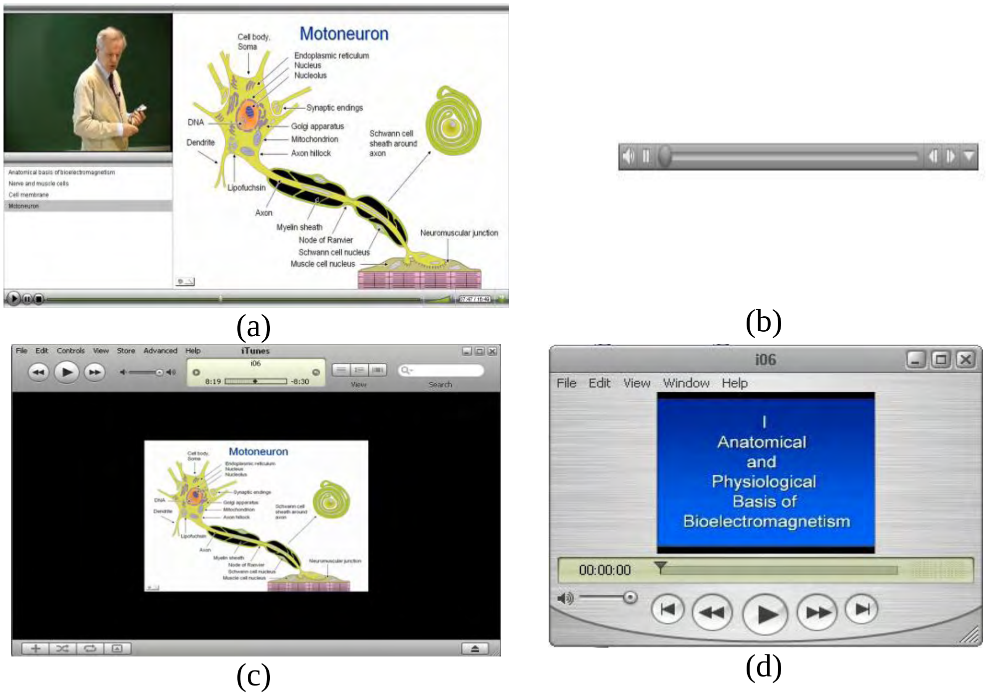


Figure 9. Examples of video lectures in different file formats: (a) video lecture accessible with PC, in Flash format; (b) audio lecture accessible with MP3 player, in MP3 format; (c) lecture for video player, accessible with iPod, in MV4 format; (d) lecture accessible with media phone, in 3GP format.

The properties of examples of video, audio lectures, also lectures for iPods and media phones in different file formats are summarized in Table 1.

Table 1. Properties of examples of video lectures.

	Case	Duration	File size	File type	Dimensions	Setting
1.	Video lecture:	00:26:24	81,82 MB	.swf, .flv, .xml, _controller.swf, _preload.swf, .html, swfobjects.js, .js, FlashTemplate.css, _nofp_bg.gif, ProductionInfo.xml	1040x595 px	
	PIP(video)		74,24 MB		320x240px	Video codec: VP6 Frame rate: 30 Video bitrates: 300 Aspect ratio: 4:3
	Audio					Format: MPEG Layer-3 Attribute: 44.100 kHz Audio Bitrates: 64kb/s
	Presentation slides		7,40 MB		720x540px	Colors: True color+(32-bit) Frame rate: 8
	Controller		185,00 KB			
2.	Audio lecture	00:26:25	12,09 MB	.mp3		Audio attributes: 44.100 k Hz, Mono Bitrates: 64 Kb/s
3.	Lecture for iPod	00:26:25	28,52 MB	.m4v	320x240px	Video codec: H.264 Frame rate: 10 Audio codec: AAC Audio bitrates: 128 kb/s
4.	Lecture for media phone	1584.81 sec	67,8 MB	.3gp	176x144px	Video codec: H.263 Frame rate: 15 Video bitrates: 261Kb/s Aspect ratio: 1.22:1 Audio codec: AAC Audio bitrates: 95 Kb/s

5.2 EVALUATIVE PART

5.2.1 Evaluation based on students' opinions

The evaluation of students' attitudes towards the virtual learning objectives is presented in Publication X. A total of 66 students of varying nationalities attended the course and provided their feedback. In general, the students' attitude towards virtual education revealed the following facts:

- The majority of students (67 percent) preferred traditional classroom learning to either virtual learning (30 percent) or blended learning (3 percent).
- Students in the initial stage of their studies (i.e., undergraduate) preferred traditional classroom lectures as the only learning method.
- Students in the advanced stage of their studies (i.e., postgraduate) found video lectures and virtual learning more useful.
- There was a minor difference in how the students evaluate the usefulness of the instructional materials. As might be expected, the traditional classroom students preferred live classroom lectures while the virtual students preferred e-book and video lectures and the blended class students found e-books and classroom lectures equally useful.
- According to the students, the most useful learning elements were animations, instructions in written format, learning materials in video format, exercises and queries on the web.
- The students want lecture handouts, virtual presentations (or videos), virtual laboratory work, virtual demonstrations and virtual exercises to be available on a virtual course.
- The students like to download video lectures to their PCs because they can be accessed multiple times and do not require Internet connection,
- The students who followed the video lectures evaluated their audio quality, video quality, presentation and pedagogical value as quite high.
- There were two types of problems, which prevented students from accessing the video lectures. These were either technical problems, such as a slow Internet connection, the lack of a Flash player or the age of their "laptop", or more general problems, such as not being familiar with the idea of video lectures or that watching the video lectures was a dull and repetitive process.
- The main reason given by students for following the video lectures was to revise and review course material.
- The main reason the students gave for not following the video lectures was simply that they preferred traditional lectures.
- Students would prefer live (i.e., face-to-face) communication or e-mailing with their educators and peers. Asynchronous

communication (i.e., online forums) and synchronous communication (i.e., audio/ video conference) were the less favored options.

- A number of the students' answers (20 percent) stated that the availability of video lectures motivated them to skip traditional classroom lectures.
- The majority of the students (79 percent) agreed that the English language is suitable for virtual learning. Conversely, about 1/4 of students would like to get some help in their native language, e.g., through subtitles.
- The feedback revealed that virtual education was quite a new endeavor for the students. Less than half of the students (40 percent) had participated in virtual courses before.
- The web-login analysis showed that virtual users accessed learning material every weekday while the traditional classroom lectures were only available for a few hours per week.

Since the students who responded to the questionnaire were able to choose whether to be anonymous or not, only 44 percent indentified themselves. It was thus possible to compare the preferred learning methods and the final examination results for this group. We divided these students into traditional classroom, virtual classroom and blended classroom students. Their final exam results appeared to be very similar, Figures 10 and Figure 11.

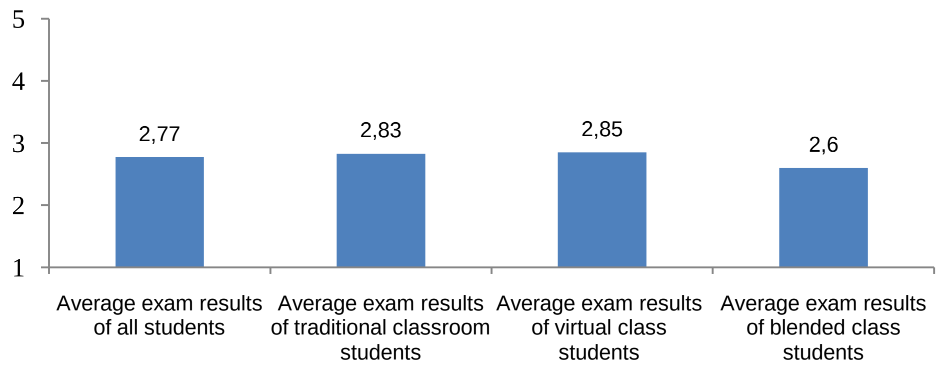


Figure 10. Comparing results of final examination, Autumn 2007.

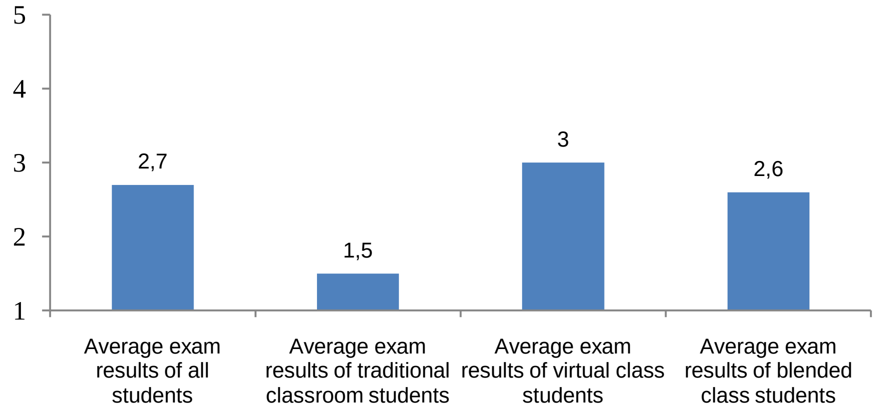


Figure 11. Comparing results of final examination, Autumn 2009.

5.2.2 Evaluation based on virtual users' accessibility

The following charts were created in order to illustrate the accessibility and usability of the virtual campus. Hits represent the total number of requests made to the server each month.

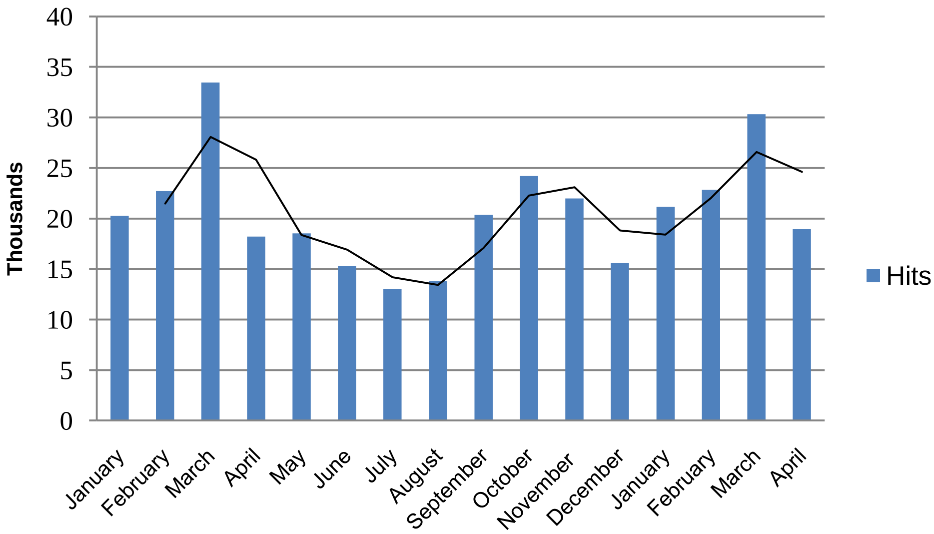


Figure 12. Number of hits for each month, 2009 and January-April, 2010.

Files represent the total number of hits (requests) that actually resulted in something being sent back to the user each month.

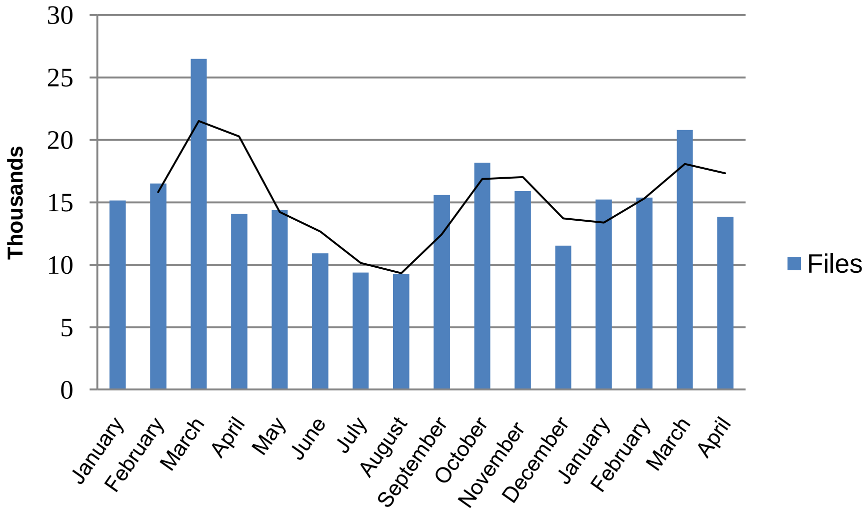


Figure 13. Number of requests (files) that resulted in something was being sent back to the user for each month, 2009 and January-April, 2010.

A visit occurred when some remote site made a request for a page on the server for the first time. As long as the same site kept making requests within a given timeout period, they were all considered part of the same visit.

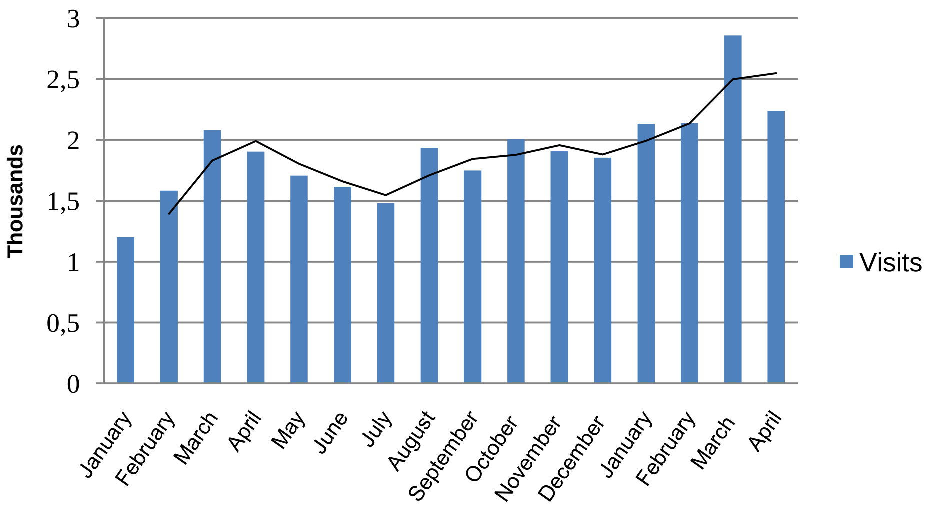


Figure 14. Number of visits for each month, 2009 and January-April, 2010.

Pages are those URLs that are regarded as the actual page being requested, and not all of the individual items that make it up (such as graphics and audio clips).

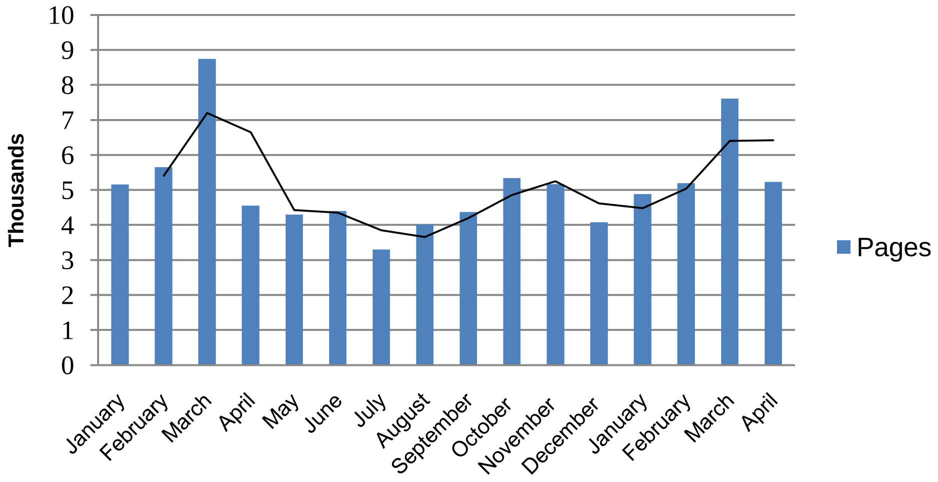


Figure 15. Number of page views for each month in 2009 and January-April, 2010.

Kbytes are used to show the amount of data that was transferred between the server and remote machine, based on the data found in the server log.

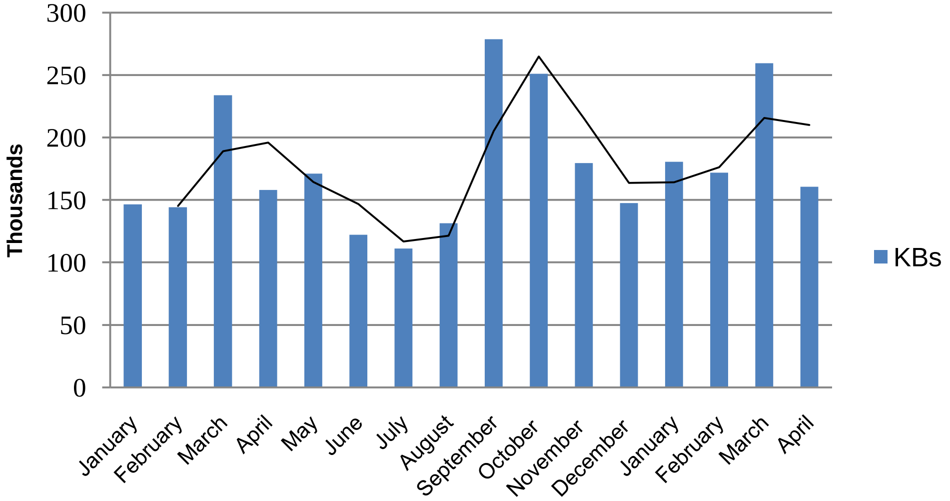


Figure 16. Total amount of data transferred from the server to machines each month, 2009 and January-April, 2010.

Figure 17 illustrates the average number of visits on weekdays. The trend line shows that number of visits is slightly greater at the beginning of the week.

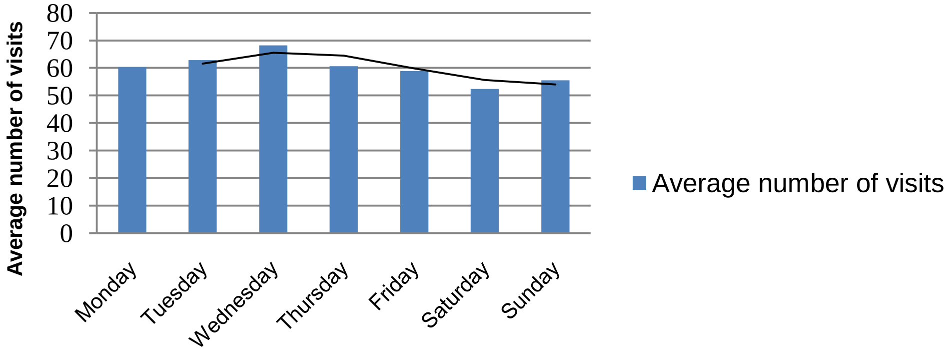


Figure 17. Average number of visits during weekdays, each month 2009 and January-February, 2010.

Figure 18 illustrates the average number of virtual visits at a certain hour, each month. The reference time is GMT+2. Based on this information it is possible to see when the server is the busiest.

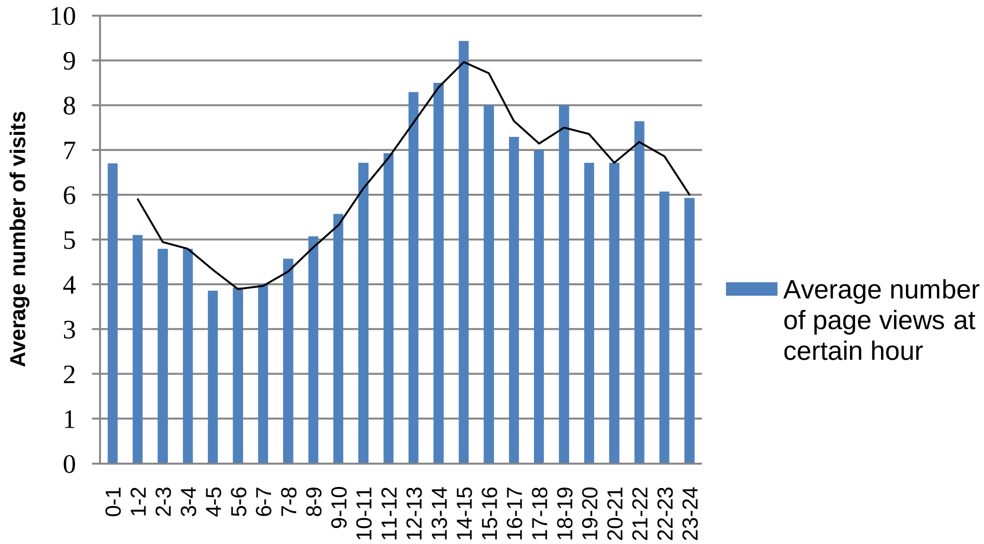


Figure 18. Average number of virtual visits at a certain hour, each month 2009 and January-February, 2010.

It was possible to ascertain the amount of information transferred to the users from the server in KBs. Naturally; video lectures account for the majority of transfers measured in this way.

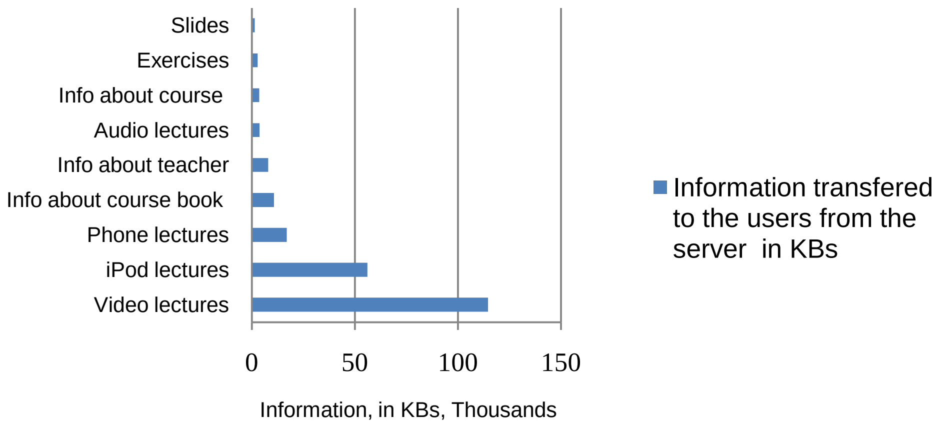


Figure 19. Amount of information transferred to the users from the server in KBs.

5.3 DEVELOPMENTAL PART

Data about e-learning development within BME in Europe was obtained by administering a questionnaire to those international educational centres offering BME education.

Education centers offering BME courses consider that tutors, literature, PCs and lab works are the most important resources.

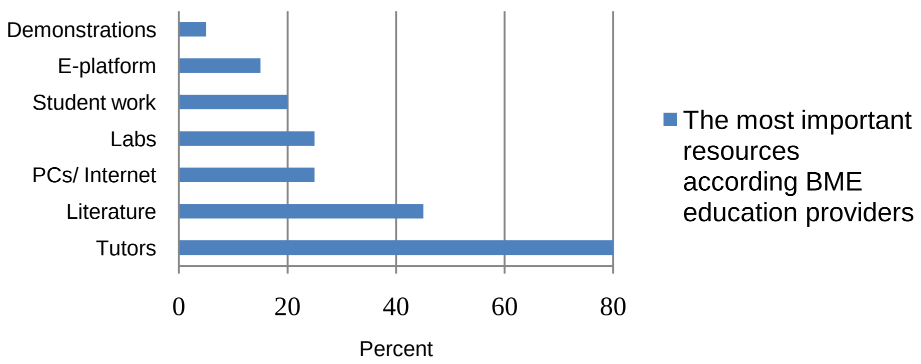


Figure 20. The most important resources supporting student learning according European education centers offering BME courses.

The majority of BME educators would be able to provide lecture materials including slides and animations for the virtual campus.

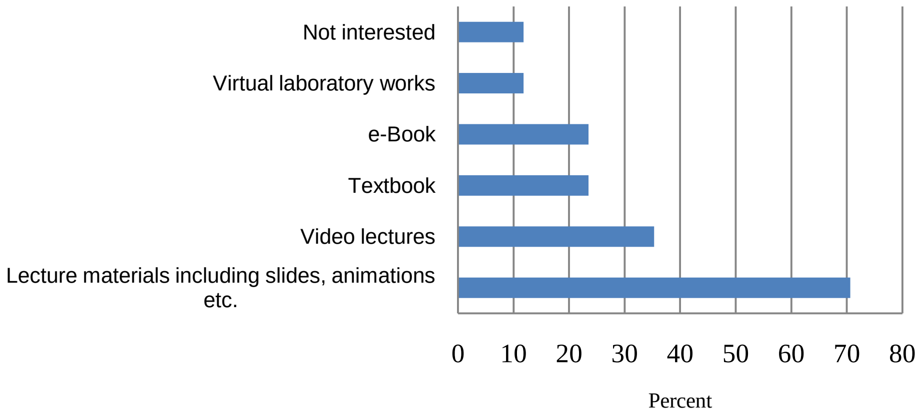


Figure 21. Resources that BME educators are able to provide to the virtual campus.

The majority of BME e-courses are at MSc level.

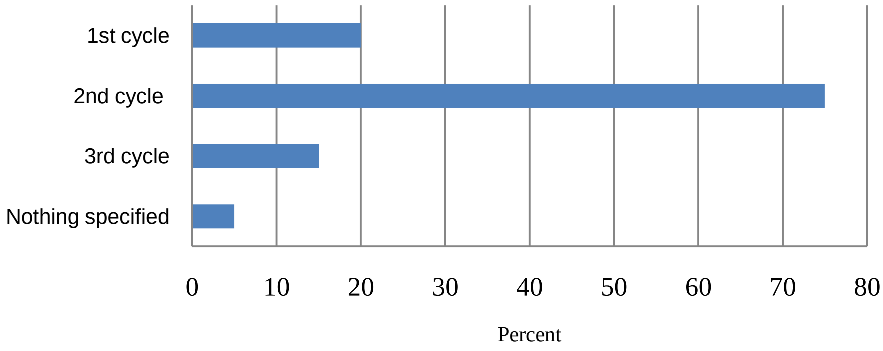


Figure 22. Most of the BME courses that European education centers offer are at MSc level.

More than half of the e-courses are available in English.

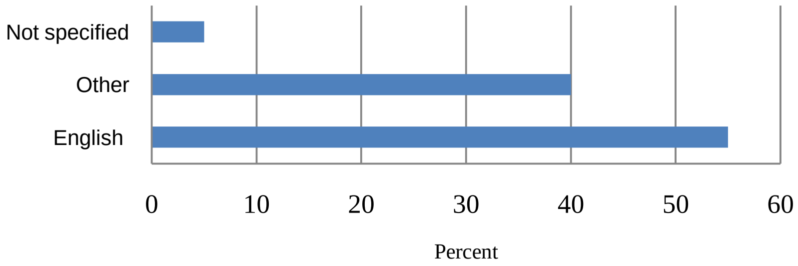


Figure 23. Languages of the BME courses that European education centers provides.

6. DISCUSSION

In this chapter observations from other publications are discussed and compared with experience obtained during this study. Also several related recommendations are provided.

Despite the fact that engineering education has seen a massive transformation over the last few decades, it has been argued that the lecturer will continue to play a central role in online education, but his/her role will become one of a learning catalyst and knowledge navigator (Volery and Lord 2000).

Many different studies about the future of education have been carried out. Felder and Silverman (1988) recommend teaching techniques for educators that address different learning methods, including e-learning nowadays, for example:

- Motivate learning, i.e., relate, as much as possible, the material being presented to what has come before and what is still to come in the same course, to material on other courses, and to the student’s personal experience.
- Provide a balance of detailed information, i.e., facts, data, real experiments and their results, and abstract concepts, i.e., principles, theories, mathematical models.
- Maintain equilibrium between material that emphasizes practical problem-solving methods and material that emphasizes fundamental understanding.

- Provide explicit illustrations of intuitive patterns, i.e., logical inference, pattern recognition, generalization, and sensing patterns, i.e., observation of surroundings, empirical experimentation and attention to detail, and encourage all students to exercise both patterns.
- Follow a scientific methodology in presenting theoretical material.
- Provide concrete examples of the phenomena the theory describes or predicts; then develop the theory; show how the theory can be validated; and present applications.
- Use pictures, schematics, graphs, and simple sketches before, during and after the presentation of verbal material. Show films. Provide demonstrations and hands-on exercises.
- Use computer-assisted instruction.
- Do not fill every minute of class time lecturing and writing on the board. Provide intervals – however brief – for students to think about what they have been told.
- Provide opportunities for students to do something active besides transcribing notes. Small-group brainstorming activities that take no more than five minutes are extremely effective.
- Provide some open-ended problems and exercises that call for analysis and synthesis.
- Give students the option for cooperation on homework assignments to the greatest possible extent. Active learners generally learn best when they interact with others; if they cannot do that – they are deprived of their most effective learning tool.
- Applaud creative solutions; even incorrect ones.
- Talk to students about learning styles. Students may be reassured to find out that their academic difficulties may not all be due to personal inadequacies. Explaining to learners about learning styles may be an important step in helping them reshape their learning experience so that they can be successful.

Educational experiments conducted by Mayer and his colleagues (Mayer 2005) on how people learn with the aid of various media revealed that people tend to learn much better from words and images that from words alone. This finding leads to empirical support for learning with video lectures. Mayer assembled a series of educational principles, which are of use in developing video lectures. The list of 9 principles includes the findings that:

- People understand a multimedia explanation better when words are presented as verbal narration alone, rather than both verbally and as on-screen text.
- People learn better when information is presented in bite-size chunks.

- People learn better when information is presented using clear outlines and headings.
- People learn better when information is presented in a conventional style rather than a formal one.
- People learn better when on-screen text is presented near any corresponding images.
- People learn better when any extraneous information is removed.
- People learn better from animation and narration than animation with explanatory on-screen text.
- People learn better when animation and narration are synchronized rather than being asynchronous.
- The design of multimedia presentation can have different effects on people depending on their prior knowledge, visual literacy, and spatial aptitude.

Producing good quality Internet teaching materials requires a production team. The resources and skills of the individual teacher are not sufficient for the production of good quality and interactive hypermedia material (Silius and Pohjolainen 2004). Whether or not e-learning can be noticeably successful and worth the investment will largely depend on the value and goals of the organization (Bartolic-Zlomislic and Bates, 2002). It is important to see virtual education as extended across the whole of the university system (Ma et al. 2000). Virtual education is not just a matter of flexible teaching and learning systems but includes administration, instructions, student recruitment, technology, research networks and library systems. Related issues are also considered in Publications VI, VII and XI.

Any future research in this field should concentrate on developing more advanced learning objects. Future learning objects should motivate students and provide them with the opportunity to test their individual knowledge, e.g., creating more intelligent and adaptable learning, such as:

- Intelligent students’ knowledge testing machine.
- Intelligent system for self-converting video lectures files.
- Intelligent video lectures (examples with subtitles and interactive survey are illustrated in Figures 24 and 25).

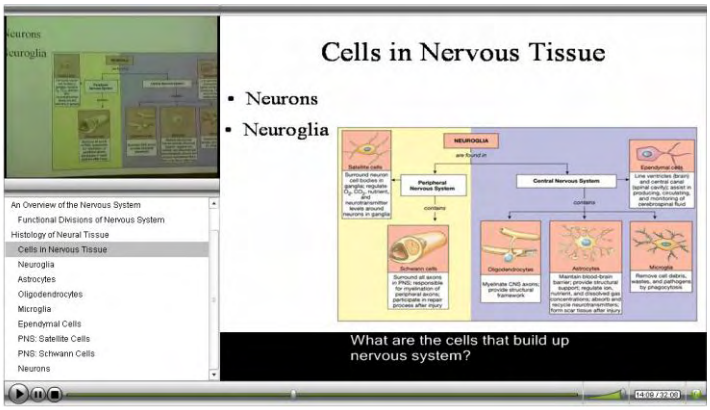


Figure 24. Video lectures with subtitles, e.g., in different native languages.

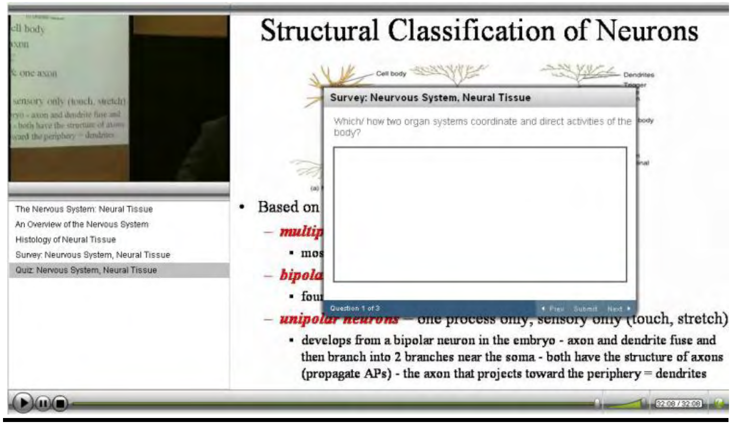


Figure 25. Video lectures with questionnaires and surveys at certain points.

7. CONCLUSIONS

The purpose of this study was to develop the virtual campus for BME, to find out how it is evaluated by students and educators and to define how it can be improved. Four different approaches were applied, i.e., theoretical, practical, evaluative and developmental. The main conclusions of this series of research are following:

- Learning theories support virtual education, e.g., by promoting more self-reliance among students, following principle of knowledge construction, applying different types and levels of learning.
- Modern technologies allow breaking the boundary of traditional classroom lecture and developing virtual education for BME.
- Virtual education is suitable for BME. It includes the system and methods, which allow immediately updating content. This is important for BME because it is a relatively fast developing discipline, where information is changing rapidly.
- Exam results showed that students who study by following traditional classroom lectures and via the virtual campus achieve very similar results, i.e., learning outcomes.
- Students can learn in the virtual campus 24 hours, every day of the week, what is not possible in the traditional class. The virtual campus is accessible for all students independent of time, location or pace.
- Students and educators become more and more interested in the opportunities that virtual campus may offer.
- Students and educators have tools in order to access virtual campus.

- Virtual education supports learning of different students, i.e., with different learning styles, e.g., visual, audio, kinematic, and with different aims, e.g., degree, exchange, visiting students (also with health problems or disabilities).
- Users all over the world are accessing the campus. Virtual education is a global education. Web-statistics proves visits coming all over the world.

8. REFERENCES

Aleamoni, L.M., 1999. Student rating myths versus research facts from 1924 to 1998. *Journal of Personnel Evaluation in Education*, vol.13, no.2, pp.153-166, 1999.

Anohina, A. Analysis of the terminology used in the field of virtual learning. *Educational Technology & Society*, vol.8, no.3, pp.91-102, 2005.

Aroyo, L. and Dicheva, D. The new challenges for e-learning: the educational semantic web. *IEEE Journal of Educational Technology & Society*, vol.7, no.4, pp.59-69, 2004.

Bacsich, P., Bastiaens, T., Bristow, S.F., Op de Beeck, I., Reynolds, S., and Schreurs, B. Reviewing the virtual campus phenomenon. The rise of large-scale e-learning initiatives worldwide*,* EuroPACE ivzw, Heverlee, 2009. Available at: http://revica.europace.org/ Re.ViCa%20Online%20Handbook.pdf. [Accessed March, 2010].

Bartolic-Zlomislic, S. and Bates A.W. Investing in online learning: potential benefits and limitations, 2002. Available at: http://bates.cstudies.ubc.ca/investing.html. [Accessed March, 2010].

Barrett, B. The Webalizer, 2009. Available at: http://www.mrunix.net/webalizer/. [Accessed February, 2010].

Benelux Bologna Secretariat. Bologna Process. Towards the European higher education area, 2009. Available at: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/. [Accessed March, 2010].

Benkeser, P. Biomedical engineering education. In *Encyclopedia of Medical Devices and Instruments*. John Wiley & Sons, Inc., 2006.

BIOMEDEA Project. Biomedical engineering education in Europe - status report, 2005. Available at: http://www.biomedea.org/Status%20Reports%20on%20BME%20in%20Europe.pdf. [Accessed March, 2010].

BIOMEDEA Project. Criteria for the accreditation of biomedical engineering programs in Europe. Institute of Biomedical Engineering, University of Stuttgart, 2005. Available at: http://www.biomedea.org/. [Accessed March, 2010].

Boulos, M.N.K., Maramba, I. and Wheeler, S. Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education. *BMC Medical Education*, vol.6, no.41, 2006.

Caruana, C. Biomedical physics education for diagnostic and therapeutic radiographers in Europe - a review. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp.123-126, 2009.

Caulfield, J. What motivates students to provide feedback to teachers about teaching and learning? An expectancy theory perspective. *International Journal for the Scholarship of Teaching and Learning*, vol.1, no.1, 2007. Available at: http://academics.georgiasouthern.edu/ijsotl/v1n1/caulfield/IJ_Caulfield.pdf. [Accessed January, 2010].

Chan, T., Hue, C-W., Chou, C-Y., and Tzeng, O.J.L. Four spaces of network learning models. *Computers & Education*, vol.37, no.2, pp.141-161, 2001.

Chandrasekhar, A.J. and Price R.N. Interactive video in medical education. *Proceedings of the Annual Symposium on Computer Application in Medical Care*, pp.1039–1040, 1989.

Christofides S., Schlegel W., Padovani R., Sharp P. F. , Torresin A., Wasilewska-Radwanska M., Wil van der Putten, Guibelalde E. and Kasch K. U . Education and training of the medical physicist in Europe. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol. 25/XII, pp. 1-4, 2009.

Cloete, E. Electronic education system model. *Computers & Education*, vol.36, no.2, pp.171-182, 2001.

Connolly, T. *Institutional Transformation Through Best Practices in Virtual Campus Development*, Idea Group Inc (IGI), 2009.

DeZure, D. *Learning from change*, Stylus Publishing, LLC, 2000.

Duhaini, I. Medical physics status in the Middle East Countries. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering*, Munich, vol. 25/XIII, pp.108-110, 2009.

Duncan-Howell, J. and Lee, K. M-learning: finding a place for mobile technologies within tertiary educational settings. In *Proceedings Ascilite Singapore,* 2007. Available at: http://eprints.qut.edu.au/12323/1/12323.pdf. [Accessed January, 2010].

Eaton, K.A., Reynolds, P.A. and Cox, M.J. Top of the pops – CD ROM and DVDs in dental education. *Br Dent J*, vol.204, no.4, pp.203-207, 2008.

Education and Culture DG. The EU contribution to the Bologna Process, Belgium. 2009, Available at: http://ec.europa.eu/education/higher-education/doc/bologna09_en.pdf. [Accessed March, 2010].

ENQA Secretariat. The European association for quality assurance in higher education. 2009, Available at: http://www.enqa.eu/. [Accessed March, 2010].

EU Commission. Europe's digital competitiveness report, 2009. Available at: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0390:FIN:EN:HTML. [Accessed April, 2010].

Felder, R. and Silverman, L. Learning and teaching styles in engineering education. *Engr. Education*, vol.78, no.7, pp.674-681, 1988.

Fominykh, M., Prasolova-Forland, E., Morozov, M., and Gerasimov, A. Virtual campus as a framework for educational and social activities, 2008. Available at: http://www.idi.ntnu.no/grupper/su/publ/fominykh/fominykh-cate08.pdf. [Accessed April, 2010].

Funderstanding, Neuroscience. Available at: http://www.funderstanding.com/content/neuroscience [Accessed April, 2010].

Golden, P., Dedieu, H. and Jacobsen, K. *Implementation and applications of DSL technology*, CRC Press, 2007.

Guangzou, C., Gongyi, Y., Hu, C., Fei, C.n and Jiuling, G. E-Learning evolution: from m-learning to educational semantic web and beyond. *Frontiers in Artificial Intelligence and Applications*, vol.151, pp.7-14, 2007.

Harris, T.R., Bransford, J. and Brophy, S. Roles for learning sciences and learning technologies in biomedical engineering education: a review of recent advances. *Annual Review of Biomedical Engineering*, vol.4, pp.29-48, 2002.

Harris, T.R. and Brophy, S.P. Challenge-based instruction in biomedical engineering: A scalable method to increase the efficiency and effectiveness of teaching and learning in biomedical engineering. *Medical Engineering & Physics*, vol.27, no.7, pp.617-624, 2005.

Holmes, A., and Brown, S. *Internal Audit in Higher Education*, Stylus Publishing, Inc., 2000.

Hwang, G-J. Criteria and strategies of ubiquitous learning. In the *Proceedings of the IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006,* vol.2*,* pp.72-77, 2006.

Kaur, P., Atan, H., Fong, S.F., Idrus, R.M., Dzakiria, H. The combination of different modalities in the web-based learning environment: A comparative analysis of the perceptual instructional outcomes. In the *Proceedings Advanced Learning Technologies, IEEE International Conference,* IEEE Computer Society, pp.764-768, 2005.

Keegan, D. *Foundations of Distance Education*, Routledge, 1994. Available at: http://books.google.com/books?id=Ab4NAAAAQAAJ [Accessed May, 2009].

Khambete, N. Biomedical engineering education and training in India - a need for new approach. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp.368-371, 2009.

Krisanachinda, A., Hoa, N.V., Lee, J.C.L., Ng, K.H., Peralta, A.P., Soejoko, D., Wong, T.J.Medical physics education and training in south east Asia. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, 25/XII, pp.143-145, 2009.

Kulik, C.C. and Kulik, J.A. Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior*, vol.7, no.1-2, pp.75-94, 1991.

LaPlaca, M., Newstetter, W. and Yoganathan, A. Problem-based learning in biomedical engineering curricula. In *Frontiers in Education Conference, 2001, 31st Annual*, vol.2, 2001.

Laurillard, D. *Rethinking University Teaching: A Conversational Framework for the Effective Use of Learning Technologies* 2nd ed., Routledge, 2001.

Lechner, S. Evaluation of teaching and learning strategies. *Med. Educ. Online*, vol.6, no.4, 2001.

Lee, J., Hong, N.L. and Ling, N.L. An analysis of students' preparation for the virtual learning environment. *The Internet and Higher Education*, vol.4, no.3-4, pp.231-242, 2001.

Linsenmeier, R. What makes a biomedical engineer? *Engineering in Medicine and Biology Magazine, IEEE*, vol.22, no.4, pp.32-38, 2003.

Llanusa, S., Rojo, N., Caraballoso, M., Urra, P.A. Improving the methodological approach to evaluate the use of information and communication technologies in primary health care in Cuba. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XIII, pp.81-84, 2009.

Luppicini, R. A systems definition of educational technology in society. *Educational Technology & Society*, vol.8, no.3, pp.103-109, 2005.

Ma, L., Vogel, D., and Wagner C. Will virtual education initiative succeed? *Information Technology and Management*, vol.1, pp.209-227, 2000.

Magennis, S. and Farrell, A. Teaching and learning activities: expanding the repertoire to support student learning. *Emerging Issues in the Practice of University Learning and Teaching*, 2005. Available at: http://www.aishe.org/readings/2005-1/magennis.html. [Accessed May, 2009].

Malmivuo, J. Evicab. *http://ww.evicab.eu*, 2007. Available at: http://www.evicab.eu/. [Accessed May, 2009].

Malmivuo, J., Nousiainen, J. and Kybartaite, A. Biomedical engineering program on the Internet for worldwide use. In the *Proceedings of 14th Nordic-Baltic conference on biomedical engineering and medical physics*, vol.20, pp.5-7, 2008.

Martini, F. and Bartholomew, E. *Essentials of anatomy and physiology* 4th ed., San Francisco, Canada: Pearson Education, 2007.

Mayer, R.E. *The Cambridge Handbook of Multimedia Learning*, Cambridge University Press. 2005,

Mochimaru, Y., Ohno, Y., Numasaki, H., Shibuya, H., Nishimura, T., Teshima, T., and The JASTRO Committee. The enhancement of the radiotherapy resources in Osaka, Japan; based on the Japanese structure survey in 2003 and 2005. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp.332-335, 2009.

Moore, A.*Teaching and learning. Pedagogy, curriculum and culture.*, RoutledgeFalmer, 2000.

Mukhtar, S.R., Harun, N.H., Jaafar, R., Abdul Kadir Bakti, Z., Talib, M.N., Roseland M.A., and Ibrahim Z. Biomedical engineering instrumentation research collaboration between Universiti Kuala Lumpur deNuo Sdn. Bhd. and Flinders University, Australia. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XIII, pp.196-199, 2009.

Nagel, J.H. BIOMEDEA. In *11th Mediterranean Conference on Medical and Biomedical Engineering and Computing 2007*. pp.1118-1121. 2007,

Nagy, A. The Impact of E-Learning. In *E-Content*. pp.79-96, 2005. Available at: http://dx.doi.org/10.1007/3-540-26387-X_4. [Accessed January, 2010].

OECD, 2007. Understanding the brain: the birth of a learning science. Available at: http://www.oecd.org/dataoecd/42/15/38813448.pdf. [Accessed April, 2010].

Opentraker.net. Opentraker.net, 2009. Available at: http://www.opentracker.net/index.jsp. [Accessed April, 2010].

Palmer, E.J. and Devitt, P.G. A method for creating interactive content for the iPod, and its potential use as a learning tool: Technical Advances. *BMC Medical Education*, vol.7, no.32, 2007.

Parliamentary Office of Science and Technology. Next generation broadband access, 2008. Available at: http://www.parliament.uk/documents/upload/postpn305.pdf. [Accessed April, 2010].

Prince, M. Does active learning work? A review of the research. *Journal of Engineering Education*, vol.93, no.3, pp.223-231, 2004.

Rae, W. Status of education and training in Africa: focus on South Africa. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XIII, pp. 25-27, 2009.

Richardson, J.T. Instruments for obtaining student feedback: a review of the literature. *Assessment & Evaluation in Higher Education*, vol.30, no.4, pp.387-415, 2005.

Richey, R., Ely, D. and Silber, K. Reflection on the 2008 AECT definitions of the field. *TechTrends*, vol.52, no.1, pp.24-25, 2008.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., Hemmo, V. 2007. Science education now: a renewed pedagogy for the future of Europe, European Commission, High Level Group on Science

Education. 2007, Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf. [Accessed April, 2010].

Rogers, D. A paradigm shift: technology integration for higher education in the new millennium. *Educational Technology Review*, pp.19-33, 2000.

Schreuders, P., and Johnson, A. A system approach for bioengineering. *Int.J. Engng Ed*, vol.15, no.4, pp.243-248, 1999.

Shah, A. and Hamid, A. Assessment and development of competency of clinical engineering practitioners - South East Asian experience. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp.324-326, 2009.

Silius, K., and Pohjolainen, S., Strategic planning for web-based learning and teaching at Tampere University of Technology, 2004. Available at: http://repub.eur.nl/resource/pub_1251/index.html. [Accessed March, 2010].

Song, L. and Hill, J. A conceptual model for understanding self-directed learning in online environment. *Journal of Interactive Online Learning*, vol.6, no.1, pp.27-42, 2007.

Stefanoyiannis, A., Psichis, C., Gerogiannis, I.,Christofides, S., Kaplanis, P.A., Geronikola-Trapali, X., Chatziioannou, S.N., Armeniakos, I., Prentakis, A. Education and training of Medical Physicists in Europe and the countries of North America: similarities-differences-general guidelines. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp.97-100, 2009.

Suh, T. The current status of medical physics in Asia-Oceania. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol.25/XII, pp. 231-232, 2009.

Weng, X., Niu, W. and Fan, Y. Educational development of biomedical engineering in China. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering,* Munich, vol. 25/XII, pp. 101-104, 2009.

Williams, J. and Fardon, M. Perpetual connectivity: lecture recordings and portable media players. In *Proceedings Ascilite Singapore 2007,* pp.1084-1092. Available at: http://www.ascilite.org.au/conferences/ singapore07/ procs/williams-jo.pdf. [Accessed March, 2010].

Volery, T. and Lord, D. Critical success factors in online education. *International Journal of Educational Management*, vol.14, no.5, pp.216-223, 2000.

Zhang, D., Zhao, J.L., Zhou, L., and Nunamaker, J.F. Can e-learning replace classroom learning? *Communications of ACM*, vol.47, no.5, pp.75-79, 2004.

The Whitaker Foundation. Available at: http://bmes.seas.wustl.edu/WhitakerArchives/glance/definition.html. [Accessed February, 2010]

9. ORIGINAL PUBLICATIONS

PUBLICATION I

Malmivuo, J., Nousiainen, J., and Kybartaite, A. Biomedical engineering program on the Internet for worldwide use. In the *Proceedings of the 14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*, Riga, Latvia, 16.-20.6.2008, pp. 5-7.

Biomedical Engineering Program on the Internet for Worldwide Use

J.A. Malmivuo, J.J. Nousiainen and A. Kybartaite

Ragnar Granit Institute, Tampere University of Technology, Tampere, Finland

Abstract — **Biomedical Engineering, which is a multi-disciplinary and fast developing field of science, covers a large number of sub-specialties. Therefore, for any university, especially for the smaller ones, it is difficult to produce and update high quality teaching material in all aspects of the field. Creating a curriculum on the Internet helps universities and students worldwide in obtaining educational material in this field.**

Keywords — **Biomedical engineering, Internet education, *www.evicab.eu***

I. Introduction

Internet is more and more used as a platform for educational material and student administration. The use of internet makes the geographical distances to disappear.

Biomedical Engineering is needed all around the world and globalization encourages the students to mobility between universities. It is important that education in Biomedical Engineering is harmonized to facilitate the mobility. The BIOMEDEA project facilitates this within the study programs in European universities.

All this gives strong reasons to develop an education program on the Internet.

This is the basis for the project: European Virtual Campus for Biomedical Engineering – EVICAB. It was funded by the European Commission Education and Training for 2006-2007.

EVICAB offers high-quality courses prepared by the best international teachers. The courses include lecture videos and associated lecture slides. The courses are also associated with additional teaching material like full textbooks, exercises, laboratory exercises etc.

All courses offered by EVICAB are recognized by at least one university in the European Union. Thus it is easy for any other university in the EU to include EVICAB courses to their curriculum.

Because the teaching material in EVICAB is available free of charge and because it can be used via Internet form anywhere in the world, the BME program provided by the EVICAB is available for worldwide use.

EVICAB uses the Wiki-idea but is more strongly controlled by an Administrative Board. This ensures that the teaching material provided by the experts is of high quality and cannot be changed by anyone else than the author. In addition to the primary teaching material, the courses have windows with free access. These are used for providing additional teaching material by the users of EVICAB. In addition to helping the students, this Wiki material may be utilized by the course author for improving the course.

The teaching material for EVICAB is provided by the best experts free of charge. The benefit from this for the teacher is that his/her reputation as an expert will be strengthened worldwide and this will support his/her career as pedagogue and scientist.

Associated to the EVICAB education there is also developed a method for Internet examinations. This will further strengthen the worldwide use of EVICAB because the geographical location of the students and the teachers does not play any role anymore.

www.evicab.eu

II. EVICAB project

The objective of the project is to develop, build up and evaluate sustainable, dynamical solutions for virtual mobility and e-learning that, according to the Bologna process,

(i) Mutually support the harmonization of the European higher education programs,

(ii) Improve the quality of and comparability between the programs, and

(iii) Advance the post-graduate studies, qualification and certification. These practices will be developed, piloted and evaluated in the field of biomedical engineering and medical physics.

Important goal is that these approaches and mechanisms for virtual e-learning can be extended and transferred from this project also to other disciplines to promote virtual student and teacher mobility and credit transfer between European universities.

III. EVICAB consortium

EVICAB is coordinated by the Ragnar Granit Institute of Tampere University of Technology. Professor Jaakko Malmivuo serves as Director of the project and Assistant Professor Juha Nousiainen as coordinator. The other partners are:

Alexei Katashev, Yuri Dekhtyar, Janis Spigulis (Eds.): NBC 2008, Proceedings 20, pp. 5–7, 2008

- Mediamaisteri Group Ltd, Tampere, Finland
- Department of Biomedical Engineering, Linköping University, Linköping, Sweden
- Biomedical Engineering Center, Tallinn University of Technology, Tallinn, Estonia
- Institute of Biomedical Engineering, Kaunas University of Technology, Kaunas, Lithuania.
- Department of Biomedical Engineering, Brno University of Technology, Brno, Czech Republic.

EVICAB welcomes interested institutes to join as associate partners. We hope that the associate partners active participate in producing teaching material to EVICAB.

IV. IDEA OF EVICAB

The fundamental idea of the EVICAB is that it offers an open platform for Biomedical Engineering curriculum on the Internet. The openness means the open access to and free right to use the resources of the EVICAB, and an open possibility for all experts in the field to contribute to the development of the content of the virtual curriculum.

Teachers, who are experienced and recognized experts in their field, are encouraged to submit full e-courses, course modules and other teaching material to EVICAB. The material may include many different formats like video lectures, PowerPoint slides, pdf-files, Word files etc.

EVICAB is not a university. The course and student administrations continue in the universities as usual: The teacher, responsible of the course/study program, may select from the EVICAB courses for the BME curriculum of the university. The students study the course either as ordinary lecturing course with the EVICAB material supporting the lectures or the course may be partially or solely studied from EVICAB. The students, or anyone even outside the university, may study EVICAB courses to add their competence in Biomedical Engineering. Thus EVICAB is important also for the persons in the working life to improving their professional competence.

The EVICAB has an Administrative Board which administers the EVICAB curriculum. The board accepts courses of sufficient scientific, pedagogical and technical quality. The board may also invite experts to provide course material to the EVICAB. Courses which apparently are of low quality, either out of date, lower quality than competing courses and not appreciated by the users of the EVICAB will be deleted. Active feedback from the users of EVICAB, both teachers and students, is essential. All this will be realized by utilizing a dynamical quality assurance system.

V. IMPACT OF EVICAB ON E-LEARNING

In its completed form, EVICAB will have strong impact on all main levels of the education process:

For students it will provide virtual mobility as a complementary, preparatory, or even substitutive option for physical mobility. The increased number on e-courses for distance learning will give higher variety of qualified studies and degrees.

Teachers will substantially benefit from the open resources, teaching materials and e-courses available through the EVICAB. The support provided for design and development, as well as the good practices and high-quality e-courses will motivate and spur the teachers in the e-course development.

EVICAB will contribute to the harmonization process of BME curricula in Europe in co-operation with BIOMEDEA and will improve the quality of the curricula. Finally, the solutions and models developed for building the virtual BME curriculum can be applied to other disciplines.

VI. INTERNET EXAMINATION

Another successful innovation and application in our e-learning activities has been the Internet examination.

In the Internet examination the students make the exam in a computer class. This may be performed simultaneously in several universities. Therefore the students do not need to travel to the location there the course was given.

The students open the Moodle program at the time of the examination and find the examination questions from there. We usually allow the students to use all the material available on the Internet. This requires that instead of asking "What is ..." the examination questions shall be formulated so that they indicate that the student has understood the topic and is able to apply this information. The only thing which is not allowed is communication with another person via e-mail etc. during the examination.

VII. MOBILE COURSE MATERIAL

One of the key issues in the EVICAB is to reach the students anywhere and anytime. The learning process should not be dependent on the location of the student. Internet based material supports this idea and hence all the educational resources are provided in the EVICAB platform in the Internet. Not only is the Internet used for media for learning process but also portable devices such as iPod and mobile phones can be used. In EVICAB project different media are supported. Students may choose the best media for his or her current lifestyle; busy student may, for instance, watch the lecture videos in a bus on the way to or from university.

VIII. WHY TO PROVIDE COURSES TO EVICAB?

EVICAB is an important teaching and learning method only if it is available free of charge and worldwide. As a consequence, the learning material should be provided free of charge.

Why experienced and competent teachers should provide such material without charge and without receiving royalties? Acceptance of a course by EVICAB will be a certificate for quality. Worldwide distribution to all university students will give exceptional publicity for the author and his/her university. All this will facilitate the sales of traditional teaching material produced by the course author. This will also attract international students from other countries all over the world to apply to the home university of the material author. We already have experience which has proven these issues to be realistic.

The Internet has dramatically changed the distribution of information. Distribution is worldwide, real time and free of delivery costs. The technology also supports wide variety of attractive presentation modalities. All this ensures wide audience and publicity for the material on the Internet. For instance, the Wikipedia dictionary serves as a successful example of this new era of information delivery. On the basis of this publicity it is possible to create markets also for traditional printed educational material. In addition the EVICAB will provide the platform for all courses free of charge. Pedagogical evaluation and technical support for course design are also provided in request. This will ensure the high quality and up to date virtual learning environment.

IX. CONCLUSION

In future, the teaching and learning will mainly be based on Internet. The ideas and the technology of EVICAB are not limited only for application on Biomedical Engineering but it may be applied to all fields and levels of education. EVICAB will be the forerunner and show the way to more efficient and high quality education

ACKNOWLEDGMENT

This work has been supported by the European Commssion Education and Training. Ministry of Education in Finland, Academy of Finland and the Ragnar Granit Foundation.

The address of the corresponding author:

Author: Jaakko Malmivuo, Prof.
Institute: Ragnar Granit Institute
Tampere University of Technology
Street: Korkeakoulunkatu 6
City: 33720 Tampere
Country: Finland
Email: jaakko.malmivuo@tut.fi

PUBLICATION II

Kybartaite, A., Nousiainen, J., Lindroos, K., and Malmivuo, J. Biomedical engineering and virtual education. In the *proceedings of Mediterranean Conference on Medical and Biological Engineering and Computing*, Ljubljana, Slovenia, 26.-30.6.2007, pp. 329-331.

Biomedical Engineering and Virtual Education

A. Kybartaite, J. Nousiainen, K. Lindroos, J. Malmivuo

Ragnar Granit Institute/ Tampere University of Technology, Tampere, Finland

Abstract— **This paper briefly presents Biomedical Engineering (BME) in the virtual education. BME is a relatively new and highly multidisciplinary field of engineering. Due to its versatility and innovativeness, BME requires special learning and teaching methods. Virtual education is an emerging trend in the higher educational system. Technologies, learning theories, instructions, tutoring, and collaboration incorporated in the virtual education can lead to effective learning outcomes. European Virtual Campus for Biomedical Engineering (EVICAB) is the platform, where traditional biomedical education is transferred to the virtual.**

Keywords — **Biomedical Engineering, Online Education, eLearning, Open Access, Collaboration.**

I. Introduction

Biomedical engineering (BME) is a relatively new field of engineering. It is under the process of continuous change and creation new specialty areas due to a large flow of information and advancements in technologies. Some of the well established specialty areas within the field of BME include bioinstrumentation, biomaterials, biomechanics, cellular, tissue and genetic engineering, clinical engineering, medical imaging, rehabilitation, and systems physiology [1]. The field of BME is very multidisciplinary as it brings together knowledge from many different sources, like medicine, technology and natural sciences.

An education can be seen as traditional and online. The traditional education is based on teacher's and students' face-to-face interactions in a class. Online education has the same meaning as virtual, internet-based, web-based, or education via computer-mediated communication. It is currently becoming popular in higher educational institutions as working students are not able to spend most of their time in a class. Meanwhile, they can attain all study related material on the internet; in the place and time which is the most convenient for them.

Due to its versatility and innovativeness a special educational environment is needed for BME. For this reason a common European Virtual Campus on Biomedical Engineering (EVICAB) is under the process of development.

II. Traditional and online education

Despite the totally different information delivering media, traditional and online education has still much in common. Books, lecture notes, exercises, laboratory works, and final exams are common elements of any class. Nowadays it is possible to convert traditional course elements to online without content modifications or loss of data. Examples of traditional and online class elements are listed in Table 1.

Although EVICAB project is in the beginning stage it already has experience in implementing the online material.

The exemplary EVICAB course, Bioelectromagnetism, refers to the book which is available for students in printed and in web edited format [2]. The web book can be accessed globally, by all students at any time. Also video lectures are provided. The lecturer's talk is recorded and compatible with alternating lecture slides. Students have the possibility to choose which lecture format to take so that their information retaining level would be the highest. The final online exam, a new dimension in learning, has also been tested. It was realized in the following way: the students attended the examination at the computer class. Their identities were checked before examination began and questions were opened on the computer. The computers were connected to the Internet and the students were allowed to use all the available material including the text books. Online examination primarily tests students' ability to understand and make conclusions on the material. The internet examination allows instructors/ lecturers to monitor the progress of the examination via the internet independently of their location.

It is not enough just to transfer the traditional material to online in order to achieve effective learning outcomes but also a pedagogical and technical support is needed as illustrated in Fig. 1.

Table 1 Traditional and Online Class Elements

Traditional Class:	Online Class:
Books	eBooks
Lectures	Audio/ Video lectures
Laboratory works	Online laboratory works
Exercises	Online tests, quizzes
Final exam	Online exam

T. Jarm, P. Kramar, A. Županič (Eds.): Medicon 2007, IFMBE Proceedings 16, pp. 329–331, 2007

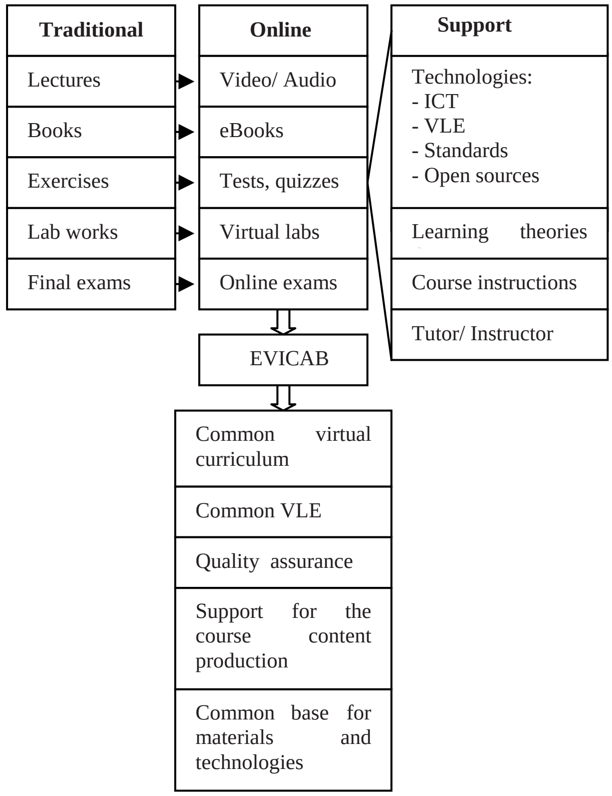


Fig. 1 Traditional and online class elements, support for the material transferring and expected outcomes by implementing courses in EVICAB

III. Support for virtual education

Technology, learning theories, course instructions, and tutors/ instructors are the key elements that support online material implementation.

Traditional and online class elements, the support, and expected outcomes by implementing courses in EVICAB are illustrated in Fig. 1.

In order to provide and apply the online material, sufficient information communication technologies (ICT), i.e., computers with internet access and software programs are required.

A virtual learning environment (VLE), in general, is defined as software to facilitate teachers in managing educational course for students. Moodle [3] was chosen as the virtual learning environment for EVICAB courses. It serves as the common platform to all courses; the material can be accessed by teachers and students at any time. Moodle also allows tracking its users' activity as every user can access the environment under own password. This VLE is not the only that can be used in EVICAB. If other course providers have already implemented their materials on the other VLE, Moodle can serve as a link to that.

Open source tools and open access learning materials are applied in preparing EVICAB courses. For example, when producing audio/ video lectures, accessing the material (e.g., flash players) or communicating and collaborating (e.g., Skype).

So that the material prepared by different authors and tools would be compatible and possible to use within VLE, Scorm [4] standard will be applied.

Lecture materials in EVICAB courses are divided into segments. Students can navigate through the whole information and choose certain parts to study. The material also can be reused and modified by adding extra information, implementing quizzes or self assessment tests.

Online materials can have a disadvantage, which is passive online reading. In order to avoid that, the online education should be based on learning theories and reasonable pedagogy, like constructivism. This approach gives students the opportunity to construct their own meaning from the information presented during virtual sessions. Learning based on constructivism is seen as active, goal oriented, self-regulated, and depended on prior knowledge and experience.

Every EVICAB course will have instructions so that students could know what prior-knowledge is needed, what are the requirements to pass the course, what can be expected after completing the course, and how will it be related with other courses. Based on this information students could plan their further studies with more motivation.

A teacher as a physical person disappears in the virtual education as all information is available online. Thus, a role of tutor/ instructor becomes important. As students will always have questions related to the course material, assignments, practical issues, organizational matters, etc., there is a need for a contact person who can answer their questions in a short time.

A direct student-to-student communication is restricted in online education. Thus, it is strongly recommended to students to communicate, collaborate, and solve common problems using any online communication technology, like discussion groups, forums, or wiki.

IV. Outcomes

This chapter outlines what outcomes have already been achieved and are expected in a long term in EVICAB. These are also illustrated in Fig. 1.

Common curriculum. Since BME is a multidisciplinary field, which brings knowledge from many different sources, it requires a wide educational background. EVICAB aims to create an open access common curriculum for all cycles of BME education. This is achieved by collaboration between partner institutions and universities, BME programmes. Currently, five partners are involved in curriculum development; they are represented by Ragnar Granit Institute, Tallinn University of Technology, Kaunas University of Technology, Linköping University, and Brno University of Technology.

Virtual Learning Environment. EVICAB uses Moodle as the virtual learning environment. It is also the platform for tutoring and communication between students and teachers. In the future the interface will improve as more courses will be available there; more teachers and students will use VLE.

High quality of online education. Since the standards for preparing and selecting the course materials are under the process of developing, the education in EVICAB has the aim to be at the highest level. This is guaranteed by quality assurance system build in EVICAB.

Support for course content production. Course designers and providers are encouraged to share their experience and tools to prepare high level online materials (e.g., experience in producing video lectures, teleconferencing).

Common recourses. EVICAB aims to create and maintain bases for open access lecture materials and for tools (e.g., software programs) used to create online courses. Course designers and providers could modify, improve, comment, and apply materials and tools for their need.

V. Conclusions

The online education is a relative new approach in learning and teaching, thus it encourages collaboration for promoting BME education. EVICAB will serve as the environment for that.

The virtual education is a challenge both for teachers and students. The effective implementation and application of BME education in the virtual environment requires not just transferring the traditional material to the online but also efficient application of technologies, learning theories, pedagogies, human assistance and collaboration between teachers, institutions, and students.

The main advantage of the virtual education is the global open access. The global learning community can be at the fingers of teachers and students. Application of learning technologies, tools, open access materials can provide a new dimension in the education and lead to effective learning outcomes.

Acknowledgment

This work has been supported by the eLearning Programme of European Commission.

References

1. Biomedical Engineering Society at http://www.bmes.org
2. Bioelectromagnetism at http://www.rgi.tut.fi
3. Moodle at http://moodle.org
4. Scorm at http://www.adlnet.gov

Corresponding author:

Author: Asta Kybartaite
Institute: Ragnar Granit Institute/ Tampere University of Technology
Street: Korkeakoulunkatu 10,
City: Tampere, 33720
Country: Finland
Email: asta.kybartaite@tut.fi

PUBLICATION III

Kybartaite, A., Nousiainen, J., and Malmivuo, J. Technologies and methods for developing a virtual campus: application for biomedical engineering education. *Computer Applications in Engineering Education,* accepted for publication in the journal, 2010.

Technologies and Methods in Virtual Campus for Improving Learning Process

A. Kybartaite, J. Nousiainen. and J. Malmivuo

Abstract— This paper presents technologies and methods that have been used when developing a virtual campus for Biomedical Engineering. Modern educational technologies have been applied to produce video lectures for personal computers, iPods, media phones, and to integrate virtual communication system. It became possible to break traditional classroom boundaries and to develop a worldwide, low-cost, modern technology-based virtual campus.

Keywords — *e-Learning, educational technology, virtual campus, video lectures*

INTRODUCTION

Teaching and learning methods are changing in modern society. A virtual campus is becoming a prominent environment for distance education [1]. No single definition exists but, in general, virtual campus [2] can be defined as an environment that uses a metaphor of university and provides users with a range of different tools for learning, e.g., online lecture notes, virtual demonstrations, online exercises and tests, examinations, lab works, forums, video teleconferences, video games, or video lectures, etc., [3-6].

A development of virtual campus is often based on social constructivism theory [7], which supports an idea that tools for learning should be applied so that dynamic and flexible environment is created and that learners can develop their knowledge also through virtual communication.

According to Debevc et al., [8] video based online lecture is one of the most powerful and information-rich form for distance education. It can provide information, which is difficult to achieve through text, graphs or verbally. Video lecture is a multimedia application with considerable promise for teaching and learning in higher education [9].

This paper presents technologies and methods that have been used when developing the virtual campus for Biomedical Engineering (BME). The work has been initialized in the project European Virtual Campus for Biomedical Engineering, EVICAB, funded by European Commission January, 2006 – December, 2007. The aim of the project was to develop, build up and evaluate sustainable, dynamic solution for virtual mobility and e-learning in the field of BME [10].

Technologies and methods for developing the virtual campus, producing and sharing video lectures, providing virtual communication and for integrating all materials in a web portal are discussed in the following chapters. The nature of presented technologies is not unique but the way they are implemented and applied for BME education is new as compared to other similar initiatives. Although video lectures are offered widely, usually they are streaming videos as can be seen from several examples in [1]. We developed an optimized method for combining different elements of lectures into reasonable and versatile educational content – video lectures, which are accessible with commonly available modern technologies. We included different educational materials, e.g., e-book, exercises, virtual models, etc., into open-access educational portal, which can easily be adapted by other educational disciplines. BME is a very multidisciplinary field combining engineering, medical and biological disciplines.

In this study we aim to answer a question: what are the current modern educational technologies (i.e., tools) that allow developing a virtual campus by anyone who is motivated? The purpose of this article is to explain these technologies and provide an example of the virtual campus.

TECHNOLOGIES and METHODS

Video lectures

Motivation. When starting to develop video lectures for BME, we considered the predominant factors. What is the purpose of video lectures and who is going to watch them? From the students' point of view the purpose of video lectures is to provide a possibility to review and revise course materials at any time, place, or pace. Also video lectures give the opportunity to study for those who are not able to participate in traditional classroom activities. Therefore, we focused on recording authentic video lectures in a traditional classroom environment instead of a studio-based environment. Also classroom environment is more natural for lecturing than a studio-based environment.

The field of BME is developing worldwide [11-14]. Therefore, not all BME education offering centers, and especially newly established ones, are able to develop and provide high quality courses for all subfields or topics. Hence video lectures and supporting educational materials available via the Internet may be used as an alternative for traditional classroom lectures.

When developing video lectures we divided the process into 5 main steps: plan, record, edit, produce, and share. Good planning involves defining objectives, analyzing technologies, evaluating students' and teachers' needs, finding possible problems and studying best-practices. Planning ahead helps to prepare for recording and obtaining better quality of video data. When originally recorded data is in good technical quality it is easier to edit it. There is no need to enhance it manually, filter audio data or compress video data. After editing it is possible to produce video lectures with lower digital space and time consumptions. When video lectures are produced in a user-friendly digital format and size, they can be more easily accessed and shared via the Internet. Therefore each step is important for the quality of video lectures. These steps are discussed in the following paragraphs.

Plan. Predominant factors boosted further questions. Where video lectures will be posted so that they are accessible by all potential users? What output format is needed? What is maximum file size or bandwidth requirement? What are the dimensions of video lectures? Small video dimensions mean small file sizes but poor visibility. Larger dimensions might not fit well for smaller screens without scrolling or scaling the content. Should video lectures include the lecturer's voice, PowerPoint Presentation (PPT) slides or portable document format (PDF), and video stream? How to combine all that data? What software programs are needed? How to set recording technique and environment? At first preliminary solutions were found and tested.

Record. We decided to combine and synchronize three elements in one application: presentation slides, video and audio data. Presentation slides, as the primary visual channel, are important elements in the lectures; they carry essential information, e.g., graphs, relevant pictures, samples of code, etc. Recorded videos from a lecturer were integrated as the secondary visual and audio channel, and illustrated in Figure 1. Recorded live lectures include not only a speaking person but also incorporate examples, questioning, discussion, humor, gestures and explanations written on the blackboard. These elements in teaching situations reduce complexity and supply more cues for understanding the matter [15]. Audio channel allows avoiding overloading of visual channels and makes the learning process more effective [16].

Presentation slides, video and audio data were integrated using optimization principle; presentation slides took 2/3 of the frame and provided important visual information; recorded live lectures took 1/6 of the frame and provided sense of presence; dynamic and synchronized table of content took 1/6 of the frame.

In order to include original presentation slides, we used screen capturing technology and recorded computer's desktop activity. The screen capture can be in the form of full motion video, still image, demonstration or program application on lecturer's computer while showing it to the classroom audience. This required installing additional software to the computer. A screen capturing and casting software may be available as commercial and open software [17]. We selected Camtasia Studio by TechSmith Corporation [25]. Screen captures were saved in .CAMREC files [18]. When it is not possible to install the screen capturing software and to record information from the computer's screen, .PPT or .PDF documents can be converted to graphic file formats, e.g., JPEG and used instead [19].

Video recordings were stored to digital video format (DV) tapes and at the same time or later transferred to digital .AVI or .WMV file format [18] using a basic video creating and editing software, e.g., Windows Movie Maker [20]. Recommendations for video recording are available elsewhere [21]. Also a short break should be taken every hour in order to reset attention of an audience [22].

Edit. Different software may be utilized for editing recorded audio and video data [23-24]. After initial editing, we applied Camtasia Studio [25] software for synchronizing video and presentation slides. Primary, secondary and audio channels were adjusted as video, picture in picture (pip) and audio tracks, Figure 2. Depending on the technical quality of data, editing can be quite time demanding manual process. The process is faster when presentation's slides are available as screen captured animations instead of still images, e.g., JPEG. It is easier to follow lectures when they are segmented into time intervals based on the topics. If the lecture is too long and there are too many topics, viewers may become distracted. Also file size becomes too large. The markers for tracking certain slides can be placed on a time line. Software [25] includes more features to enhance video lectures, e.g., dynamic table of content, callouts, captions, zooming, flash quizzes and surveys.

Produce. Adobe Flash player is widely distributed multimedia and application player [26]. It uses vector graphics to minimize file size and to create files that save bandwidth and loading time [27]. Flash has become a common format for animations and videos embedded into web pages. This player is built into recent version browsers or available as plug-in. Adobe Flash is supported on Macs, Linux and Windows workstations. We selected a very common .FLV file format [18] for video lectures.

The display resolution for video lectures were selected so that it suits different computer screens and do not require scrolling or scaling the format too much, Table 1. The number of pixels of common computer screens usually varies between 640x480 to 2048x1536 pixels with aspect ratio 4:3 [28].

In the final production file (of each video lecture) we obtained the flash file and ten supporting files. The total files' size averaged from 20 to 100 megabytes (MB), i.e., 80 MB is about 20 minutes of video lecture. All the files were placed on the server so that the lectures are accessible via the Internet.

Share. Not all viewers may have technology advanced skills and their computer set-up might restrict their capability to see the video lectures [27]. Therefore, the lectures should put as few technical constrains to the viewers as possible. We tested that the minimum bandwidth should be 350 kilobits per second (Kb/s), but it is recommended 1 Mb/s to watch the lectures without buffering pauses. Larger bandwidths are becoming more and more available (e.g., DSL technologies [29]), but still this might be true only for certain countries. Using the global broadband speed test [30] we obtained the following data e.g., in Finland the average available bandwidth for downloading is 7.8 Mb/s, in Europe – 6.4 Mb/s, global – 5.5 Mb/s, whereas in Asia, e.g., Bangladesh (Dhaka city) - 0.42 Mb/s. Another issue to consider is the bandwidth problem on the source site – what can happen to the server if it gets hundreds of requests at the same time for video lectures? We placed the lectures on the university server and did not experience related problems so far. It is also possible to upload videos on external servers [31-32].

Another way to reduce bandwidth is to minimize video resolution; but this may lead to a low quality of the video lectures, which cannot be watched anymore. These choices could be defined at the beginning of the production of video lectures and not modifiable; or dynamic – adjusted in response to the time and needs.

Video lectures for personal, portable and mobile gadgets

We considered how video lectures can be further utilized. Streaming requires permanent Internet connection [33]. It is possible to make a downloadable compressed file containing lectures to be played later locally on the viewer's computer. Transferring the compressed file can happen at lower speed but when it is downloaded it can be played multiple times and does not require Internet connection. Another possibility is distributing the video lectures on digital versatile disks (DVDs).

A video files converting software was used to obtain MP3, MP4 and 3GP [18], [34] files for audio, video players, and mobile phones. It became possible to access files with free software, i.e., iTunes and QuickTime player [35-36] and then upload them to personal gadgets.

We produced MP4 files with one visual channel, i.e., recorded presentation slides and audio channel. These files were made to be accessible with iPods, e.g., 320x240 screen resolution; also other players could be used [37]. Capability of mobile phones is increasing every day. So in addition, we experimented with media phones by producing and uploading 3GP file format. Nowadays there exists different audio and video conversion software, which allow achieving various compatibility file formats [38]. When producing the video lectures it should be considered which file format is needed and can be used for a certain application.

Virtual communication

Interactivity is a critical component of teaching and learning [39]. It is especially important in a virtual education due to the distance and time difference between an educator, students, and peers. WordPress blog tool and publishing platform [40] was implemented as an asynchronous communication system. All users have the possibility to leave their comments, messages, and suggestions in the system as it does not require registration. A rating system was added so that the users could evaluate information within each lecture, which consists of several video records.

Web portal

We used Hypertext Markup Language (HTML) to implement learning materials in the web portal [41]. It's code maybe used as an open source. It is possible to contribute to the code development first downloading it to own computer. Layout of the portal has been considered so that accessibility and usability of the campus is as easy and user-friendly as possible. HTML can execute on a PC under Windows or OS/2, on a Mac, or on a UNIX workstation. The web portal has been optimized for the Mozilla Firefox browser.

Feedback questionnaire

The above mentioned materials and methods have been applied when implementing Bioelectromagnetism course at Tampere and Helsinki Universities of Technology. Students with several different native languages attended the course. The course was offered both in the traditional classroom environment and in the virtual campus. A questionnaire was developed to collect feedback from 66 students, who participated in the course, for preliminary evaluation of the implemented methods. The questionnaire included 20 closed- and open-ended questions. Students had the possibility to express opinions by selecting one or more answers from multiple-choice questions and commenting in own words. Several answers had a grading system – Likert scale from 1 to 5; where grade 1 was for not useful and grade 5 meant very useful. Students were asked to answer questions as accurately as possible. The information obtained from the feedback was collated into charts; one of them is displayed in Figure 6. Average values were calculated for the answers, which had Likert scaling. The detailed evaluation and reflection of feedbacks will be prepared as a separate publication.

RESULTS

Virtual Campus

The virtual campus for BME has been developed by using the above presented technologies and methods. Architecture of the presented system is illustrated in Figure 3. The campus provides possibility to build up, implement, test and prove importance of virtual education on the global scale. It is open for all students as they may access its content without any required password and no fee is asked for using learning materials. The campus provides a platform to share learning materials prepared by distinguished international lecturers. Modern information communication technologies (ICTs), e.g., notebooks, video and audio players or media phones may be applied to access the system.

Learning materials and accessibility

We developed own method to produce the video lectures. In order to make the lectures independent of only one type of device, i.e., PC, and to make them accessible anytime and anywhere, files were transformed to be compatible with personal, portable and mobile gadgets. We were mainly interested in the application of iPods and media phones for educational purposes. The video lectures lack interactivity, e.g., possibility to ask questions or express opinion, therefore communication and rating system was implemented.

We collected learning material and related information in to open-access and user-friendly web portal. Web log-ins showed that the users mainly accessed the virtual campus via Firefox browser using Windows operating machines, Figure 4. This information was important since not every browser on every operating system is able to correctly decode video files. The Log-ins system counted on average 40 visits coming from all over the world every day, Figure 5. This information proved that the virtual campus has been accessible.

Evaluation with questionnaires

Feedback results revealed that students appreciate the advantages of the virtual campus, e.g., ‘virtual class can be attended anytime and anywhere’, ‘virtual class offers the possibility to revise concepts’, etc. Despite that, still the majority of the students (67%) considered traditional class as the main learning method; the most common reason for that is: ‘it is easy to participate in traditional lectures and there is a possibility to ask’. BME students would like learning material in video format, animations and instructions in written format to be included in a virtual course, Figure 6. Nowadays all students claim to have access to PCs; 38% of them use audio and video players for their studies. Progressively teachers and students become more and more interested in the possibilities that virtual education may provide, i.e., ‘it would be nice to have more virtual courses’.

DISCUSSION

Presented methods and technologies for developing the virtual campus are not new endeavors. Video lectures have been developed by many educational institutions [42-45]. They provide collections of academic videos for different scientific fields. These videos show a lecturer and what he / she presents on a blackboard. Most of these videos are directly recorded from a lecturing hall presenting the lecturer and a set of PPT slides. Some of these videos form lectures, which are the material for a certain course, but there is no information on credit units and about the possibility to take an examination.

We were looking for innovative implementation and application methods of video lectures for BME discipline. The virtual campus, EVICAB, provides edited video lectures in a form of combination of recorded live lectures, accompanying sound and synchronized presentations. They form certain courses recognized by international universities. Students can take the exam after following these lectures and earn credits for their studies.

We agree that video lecture is a multimedia application with considerable promise for teaching and learning in higher education [9]. In general, the main advantages of video lectures for students are (also for teachers): (1) grasping students' attention and motivating them to learn, (2) providing highly realistic depiction of situation which students would not otherwise have possibility to see, e.g., medical procedure, (3) providing possibility to watch again/ later recorded lectures until a skill is mastered or information is comprehended, (4) allowing students to catch up if they miss a live lecture, (5) enhancing flexibility to choose learning place, time and pace, etc. Video lectures also have disadvantages such as: (1) watching video lectures may become a dull and repetitive process, (2) no direct interaction with lecturer and peers limits possibility to ask questions, (3) computer access or Internet connection might be not available, (4) fast accessing of information might diminish the importance of constructing knowledge, etc.

In order to utilize advantages and to find solutions for disadvantages of video lectures we combined supporting materials, i.e., lecture slides, online quizzes and exercises, animations, e-book, virtual communication system, etc.

We realized that the students are not so willing to communicate via the virtual communication system. This may be due to a fact that the students are not familiar with such a system; they assume that nobody will respond or it is faster and more probable to get a feedback when communicating directly to a person than through the virtual system.

In engineering education deeper learning and longer retention of what has been learned can be achieved by making laboratory works. Real laboratories are not accessible for virtual students, therefore interactive experiments using software tools can help students to grasp difficult theoretical concepts and develop certain skills. There is a wide range of examples when commercial or open source software programs have been applied in a virtual course. However, often it is difficult to implement software programs in a suitable and pedagogical way; that requires good software skills and consumes a lot of time. Another problem with software programs for teaching and learning is their relatively short life cycle (often less than 5 years) [46]. So far we have been researching different software programs and started to collect them under tutorial links in the web portal. These practices can provide insights what virtual laboratory works are necessary for BME students and how to develop them.

The Internet has significantly changed the distribution of information. Nowadays information is accessible worldwide, real time and free of delivery cost. That ensures wide audience and publicity for learning materials on the Internet. It is possible to identify at least three groups who are direct beneficiaries from virtual education; they are students, instructors and university administrators [47].

CONCLUSION

Nowadays technologies and methods are available and relatively user friendly for developing the virtual campus for higher education. Anyone who is interested in developing or contributing to the virtual campus is able to do that. Thus new technical boundaries may appear. They can be diminished by considerate technology analysis and design.

Findings of this study for BME discipline proved that the virtual campus for higher education is feasible.

References

[1] Re.ViCa, Virtual Campus, http://www.virtualcampuses.eu/index.php/Virtual_campus, updated Fall 2009, accessed November 2009.

[2] M. Fominykh, E. Praslova-Forland, M. Morozov, and A. Gerasimov, Virtual campus as a framework for educational and social activities, http://www.idi.ntnu.no/grupper/su/publ/fominykh/fominykh-cate08.pdf, 2008, accessed November 2009.

[3] D. Dwyer, K. Barbieri, and H. Doerr, Creating a virtual classroom for interactive education on the Web. Computer Networks and ISDN Systems, 27 (1995), 897-904.

[4] M. L. Maher, B. Skow, and A. Cicognani, Designing the virtual campus. Design Studies, 20 (1999), 319-342.

[5] S. Schultze-Mosgau, T. Zielinski, and J. Lochner, Web-based, virtual course units as a didactic concept for medical teaching, http://informahealthcare.com/doi/abs/10.1080/01421590410001679028, 2004, accessed. November 2009.

[6] M. Karami, N. H. Heussen, T. Schmitz-Rode, and M. Baumann. Advantages and disadvantages of electric assessment in Biomedical Engineering, IFMBE proceedings, World congress on Medical Physics and Biomedical Engineering, 25 (2009), 61-64.

[7] A. Moore, Teaching and learning. Pedagogy, curriculum and culture, Routlege, 2000, 189.

[8] M. Debevc, R. Safaric, and M. Golob, Hypervideo application on an experimental control system as an approach to education. Computer Application in Engineering Education, 16 (2008), 31-44.

[9] J. Whatley and A. Ahmad, Using video to record summary lectures to aid students' revision, Interdisciplinary Journal of Knowledge and Learning Objects, 3 (2007), 185-196.

[10] J. Malmivuo, EVICAB, http://www.evicab.eu/, accessed November 2009.

[11] C. Brancaleone, R. Tranfaglia, L. Mirarchi and M. Bracale, An e-learning experience for medical education in Mediterranean countries, 2009, IFMBE proceedings, World congress on Medical Physics and Biomedical Engineering, 25 (2009), 271-274.

[12] N. D. Khambete, Biomedical engineering education and training in India – a need for new approach, IFMBE proceedings, World congress on Medical Physics and Biomedical Engineering, 25 (2009), 368-371.

[13] X. Weng, W. Niu, and Y. Fan, Educational development of biomedical engineering in China, IFMBE proceedings, World congress on Medical Physics and Biomedical Engineering, 25 (2009), 101-104.

[14] M. Wasilewska-Radwanska and P. Augustyniak, Multidisciplinary school as BME teaching option, IFMBE proceedings, World congress on Medical Physics and Biomedical Engineering, 25 (2009), 200-203.

[15] Y. Fritze, and Y. T. Nordkvelle, Comparing lectures: effects of the technological context of the studio. Education and Information Technologies, 8 (2003), 327-343.

[16] R. E. Mayer, The Cambridge Handbook of Multimedia learning, Cambridge University Press, 2005, 5.

[17] Wikimedia Foundation, Inc. Comparison of screencasting software, http://en.wikipedia.org/wiki/Comparison_of_screencasting_software, 2009, accessed May 2009.

[18] Video files, http://www.fileinfo.com/filetypes/video, 2005-2009, accessed November, 2009.

[19] J. Miano, Compressed Image File Formats, Addison-Wesley, 1999.

[20] Microsoft Corporation, Windows movie maker, http://www.microsoft.com/windowsxp/using/moviemaker/default.mspx, 2009, accessed June 2009.

[21] Learn video production, digital video editing, camcorder reviews, videography, http://www.videomaker.com, 2009, accessed May 2009.

[22] P. Aarabi. The art of lecturing. Cambridge University Press, 2007.

[23] Wikimedia Foundation, Inc. List of free software for audio, http://en.wikipedia.org/wiki/Free_audio_software, 2009, accessed May 2009.

[24] Wikimedia Foundation, Inc. Comparison of video editing software, http://en.wikipedia.org/wiki/Comparison_of_video_editing_software, 2009, accessed May 2009.

[25] TechSmith Corporation. Camtasia Studio, Screen Recorder Software, http://www.techsmith.com/camtasia.asp, 1995-2009, accessed November 2009.

[26] Adobe Systems Inc., Adobe Flash Player, http://www.adobe.com/products/flashplayer/, 2009, accessed November 2009.

[27] M. Ronchetti, Requirements for video lectures: which system is the best for you? http://latemar.science.unitn.it/segue_userFiles/LODE/RequirementsForVideolectures.pdf, 2009, accessed November 2009.

[28] Wikimedia Foundation, Inc. List of common resolutions http://en.wikipedia.org/wiki/List_of_common_resolutions, 2009, accessed November 2009.

[29] P. Golden, H. Dedieu and K. Jacobsen, Implementation and application of DSL technology, CRC Press, 2007.

[30] Speedtest.Net – The Global Broadband Speed Test, http://www.speedtest.net, 2009, accessed November 2009.

[31] TechSmith Corporation. Screencast.com, http://www.screencast.com, 1995-2009, accessed November 2009.

[32] Yovisto – Academic video search, http://www.yovisto.com, 2006-2009, accessed November 2009.

[33] G. Conklin, G. Greenbaum, K. Lillevold, A. Lippman, and Y. Reznik, Video coding for streaming media delivery on the Internet. IEEE Transactions on Circuits and Systems for Video Technology, 11(2001), 269-281.

[34] Audio files, http://www.fileinfo.com/filetypes/audio, 2005-2009, accessed November 2009.

[35] Apple Inc. iTunes, http://www.apple.com/itunes, 2009, accessed November 2009.

[36]Apple Inc. QuickTime Player, http://www.apple.com/quicktime, 2009, accessed November 2009.

[37] Wikimedia Foundation, Inc. Comparison of portable media players, http://en.wikipedia.org/wiki/Comparison_of_portable_media_players, 2009, accessed November 2009.

[38] Wikimedia Foundation, Inc. Comparison of container formats, http://en.wikipedia.org/wiki/Comparison_of_container_formats, 2009, accessed November 2009.

[39] K. Siau, H. Sheng and F. Nah, Use of a classroom response system to enhance classroom interactivity. IEEE Transactions on Education, 49 (2006), 398-403.

[40] WordPress.com, http://wordpress.com, accessed May 2009.

[41] Web files, http://www.fileinfo.com/filetypes/web, 2005-2009, accessed November 2009.

[42] Webcast.berkeley, http://webcast.berkeley.edu, 2002-2009, accessed November 2009.

[43] MIT open course ware, http://ocw.mit.edu/OcwWeb/web/home/home/index.htm, 2002-2009, accessed November 2009.

[44] Video Lectures – exchange ideas and share knowledge, http://videolectures.net, 2009, accessed November 2009.

[45] Free video lectures. World's best professors are teaching here. Where are you? http://freevideolectures.com, 2009, accessed November 2009.

[46] S. Tabakov, E-Learning development in medical physics and engineering, Biomedical Imaging and Intervention Journal, http://www.biij.org/2008/1/e27, 2009, accessed December 2009.

[47] L. Ma, D. Vogel and C. Wagner, Will virtual education initiatives succeed? Information Technology and Management, 1 (2000), 209-227.

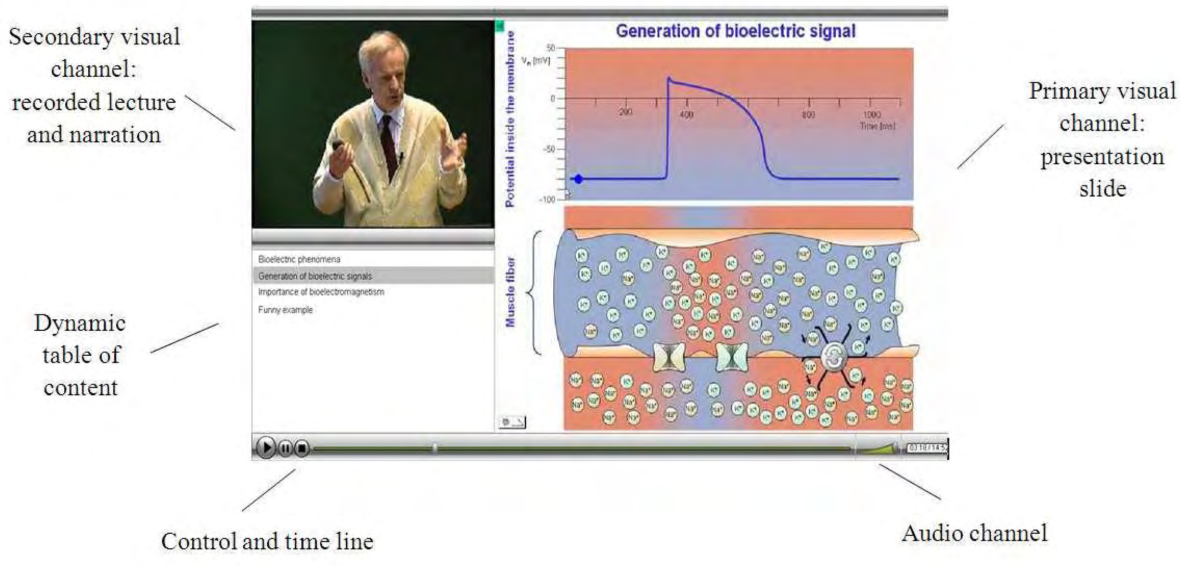


Figure 1. Elements of video lectures

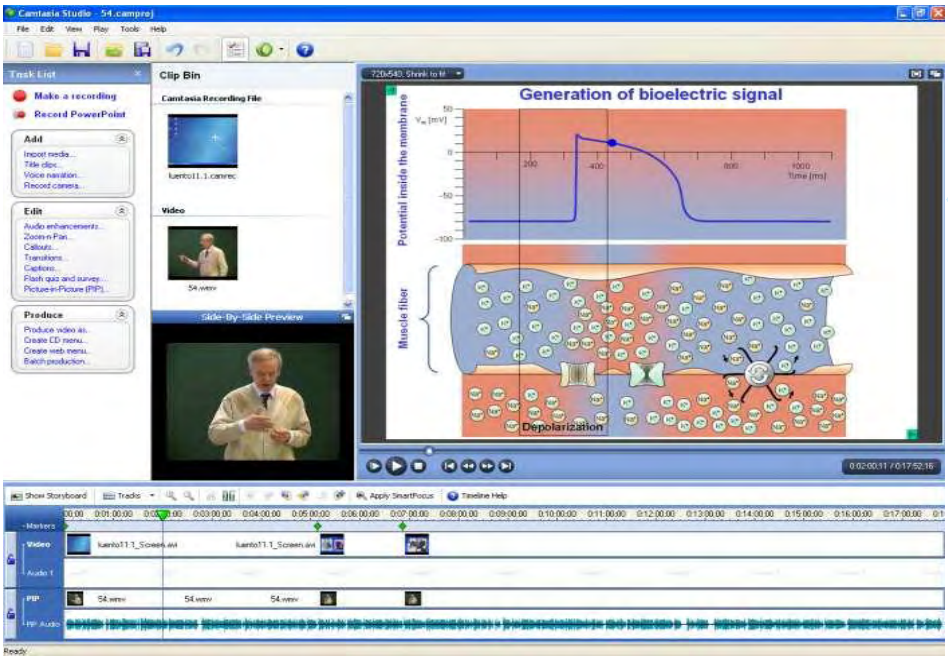


Figure 2. Editing window for video lectures

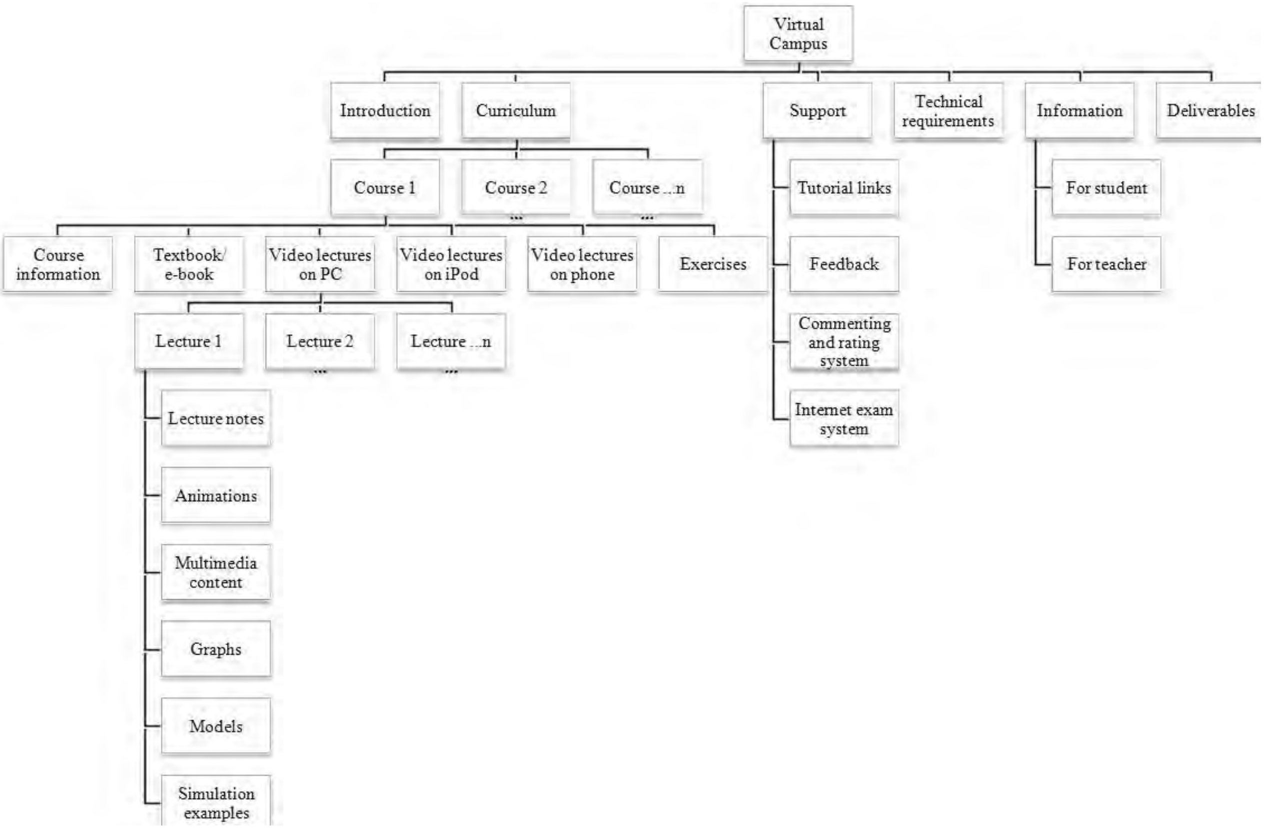
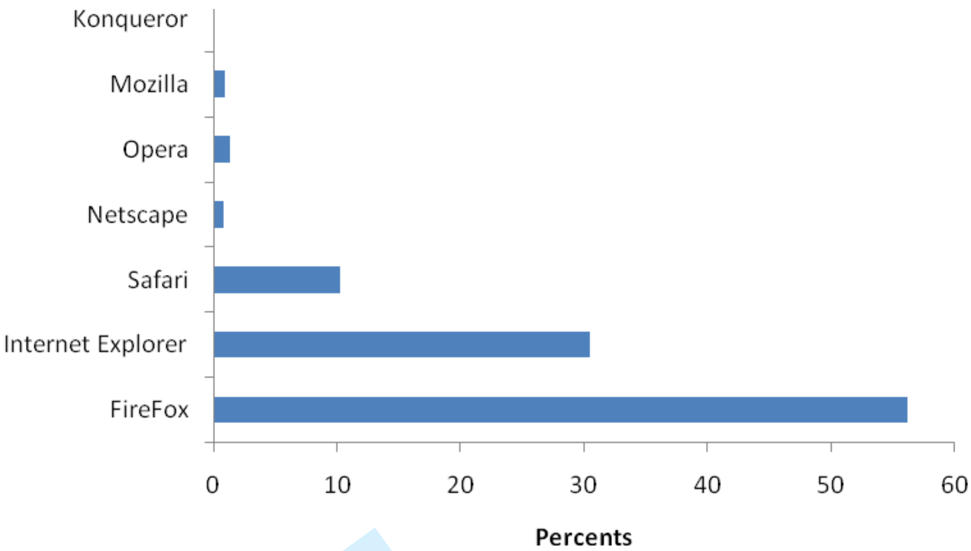


Figure 3. Main architecture of the virtual campus design



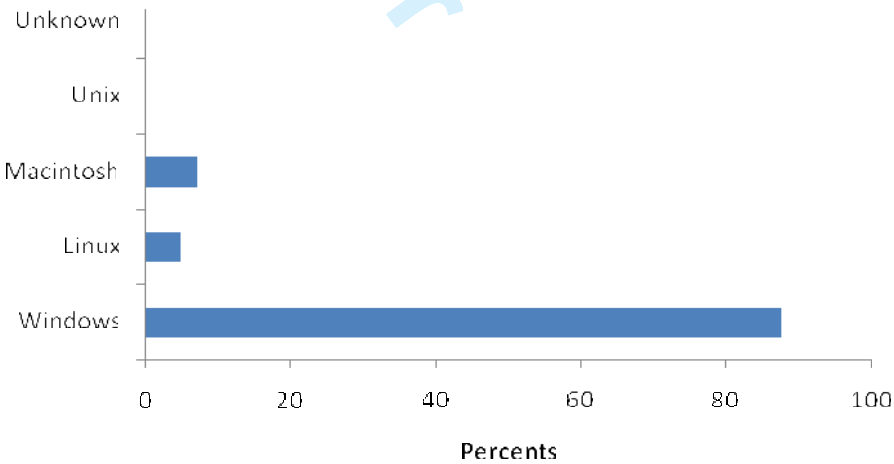


Figure 4. Browsers and operating machines used to access Virtual Campus

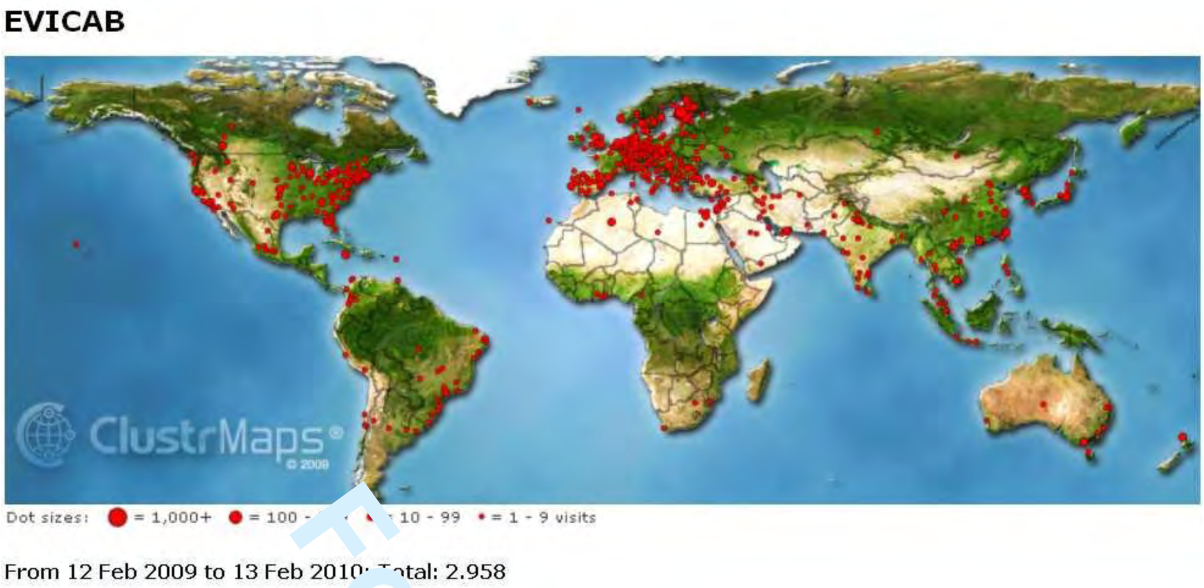


Figure 5. Statistics about EVICAB virtual visits since 12 February, 2009.

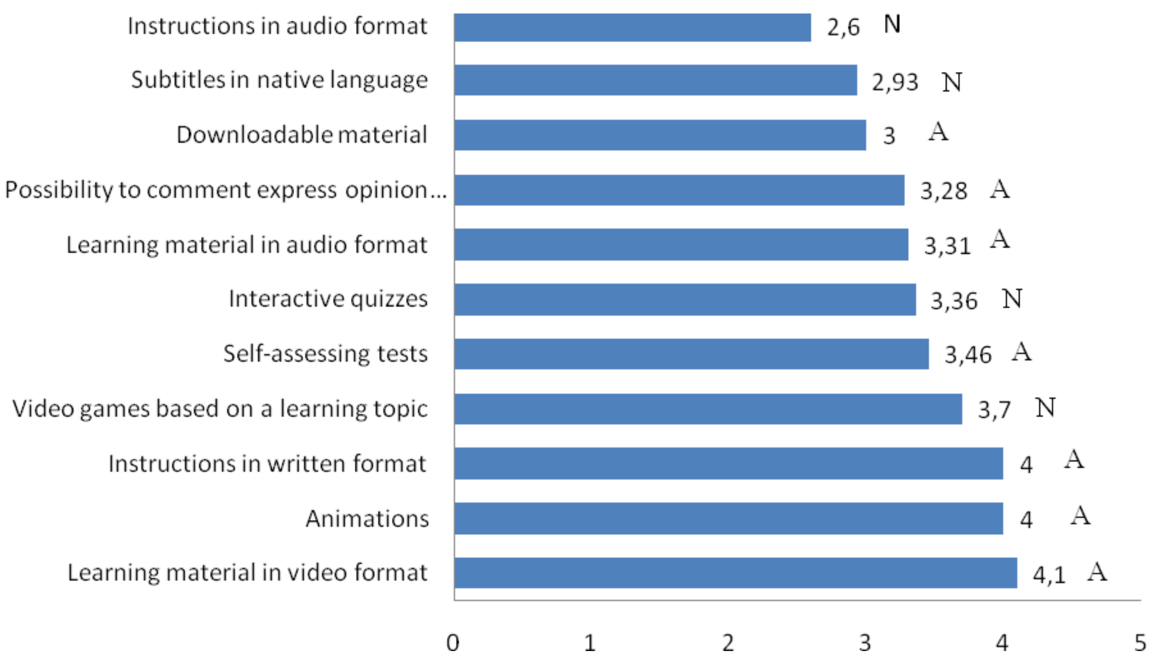


Figure 6. Anticipated usefulness of learning elements within the virtual course presented as averages. Evaluation scale was from 1 (not useful) to 5 (very useful). A: Learning elements were available in the virtual campus; students have possibility to test them. N: Learning elements were not available in the virtual campus; students anticipate their usefulness.

TABLE 1

Display resolution of the video lectures

Elements of video lectures	Dimensions (in pixels, height and width)
Total	1040x595
Primary video channel (slides)	720x540
Secondary video channel (video record)	320x240

PUBLICATION IV

Kybartaite, A., Nousiainen, J., and Malmivuo, J. Learning objects for the virtual campus of biomedical engineering. *IEEE Multidisciplinary Engineering Education Magazine (MEEM),* accepted for publication in the journal, 2010

Learning Objects for the Virtual Campus of Biomedical Engineering

A. Kybartaite, J. Nousiainen and J. Malmivuo, *Fellow, IEEE*

***Abstract*—In this paper we briefly present the learning objects that have been implemented in the European Virtual Campus for Biomedical Engineering, EVICAB. Learning objects are fundamental elements for the creation and distribution of e-learning. Not only do high quality and pedagogically sound learning objects lead to better learning outcomes but they also provide a solid basis for the establishment of new programmes in educational institutions.**

***Index Terms*—Biomedical engineering, educational technology, learning objects, resource management**

I. Introduction

Innovative teaching techniques and effective instructional materials maximize opportunities for students' learning in every lesson [1]. They are particularly important for relatively new and multidisciplinary fields like Biomedical Engineering (BME), where educators have to consider how to introduce students to techniques applied in traditional engineering disciplines such as electrical, mechanical and chemical engineering and the biology based disciplines of life science and medicine [2] while simultaneously teaching them how to apply these concepts in new ways and to the type of biological systems not found in any other engineering discipline [3].

The traditional way of transferring knowledge effectively to students may fail regardless of the lecturer's sound knowledge of the subject area. This occurs because it is often hard for students to fully comprehend material while simultaneously taking notes and listening to the lecturer. [1]. Therefore, the lecture quite often functions as a one-way channel for the delivery of information.

The literature review has thrown up a wide list of examples where innovative teaching techniques and effective instructional materials were created, developed and applied for BME. For example, Harris and Brophy [4] stated that effective instruction should be knowledge-, student-, assessment- and community-centered. The authors also considered that challenge-based instruction (CBI) could be an effective instructional model, where students apply their inquiry skills, explore multiple applications for the content, and work with an instructor's guidance [4]. LaPlace et.al, [2] suggested that problem based learning (PBL) is well-suited for students within the interdisciplinary field of BME. Giuffrida [5] stated that BME education requires hands-on learning with cutting edge technology in order to train students to solve clinical problems in research and industry. Since real laboratories are not always available for students, learning with the aid of information communication technologies (ICT) may bridge the gap between theoretical and practical approaches. Trumbower and Enderle [6] have pointed out that virtual instruments imitate physical instruments and promote hands-on, real-world experiences, develop measurement skills, help to learn engineering theories and practical applications relevant to medicine and biology. Web 2.0 applications such as wikis, blogs and podcasts have been successfully adopted by health care professionals and education services [7]. Bar et.al, [8] have provided examples of instruction where numerous video-audio clips were given as background information for students learning biomechanics.

These examples show that traditional teaching techniques and instructional materials for delivering engineering education are gradually becoming more efficient and effective in that they are more personalized, flexible, portable, and readily available on demand. The starting point for innovative teaching techniques and effective instructional materials is the creation of learning objects.

This paper aims to review the characteristics of good learning objects and to describe those which were developed and implemented for EVICAB, the European Virtual Campus for Biomedical Engineering. EVICAB aims to develop, build and evaluate sustainable, dynamic solutions for virtual mobility and e-learning in the field of BME [9].

II. Learning Objects

A. Literature Review

Learning objects are fundamental elements for content creation and distribution [10]. However, the definition of learning objects still causes confusion as different authors have diverse views [11].

The IEEE Learning Technology Standard Committee defines learning objects as "…any entity, digital or non digital, which can be re-used or referenced during technology supported learning [12]". Examples of learning objects may include multimedia content, instructional content, learning objectives, instructional software and software tools, as well as the persons, organizations or events referenced during technology supported learning [12]. Sosteric and Hesermeier [13] have argued that the definition for a learning object should be narrowed to "…a

Manuscript received June 15, 2009.

Authors are with the Department of Biomedical Engineering, Tampere University of Technology, PL 692, 33101 Tampere FINLAND (e-mail: asta.kybartaite@tut.fi).

digital file (image, movie, etc.,) intended to be used for pedagogical purposes, which includes, either internally or via association, suggestions on the appropriate context within which to utilize the object". According to McGreal [14] learning objects are sometimes defined as educational resources that can be employed in technology-supported learning. They can be modular units based on an electronic text, a simulation, a Web site, a .GIF graphic image, a QuickTime movie, a Java applet or any other resources that can be assembled to form lessons or courses. Miller et.al, [15] defined learning objects as "…usually a small digital or non-digital file (like text, images, audio and video) or module that, when integrated with other learning objects, make up course content. Learning objects are reusable resources that can be used in a variety of contexts, across disciplines and institutions. It is a resource that can be modified to suit various academic teaching styles and methods and further enhance the objectives of the course".

B. Levels of Development

In this paper we are interested in learning objects for e-learning and the virtual campus.

The most common definition states that "e-learning is facilitated and supported through the use of information and communication technology (ICT)" (widely quoted without citation). E-Learning involves the interaction of a number of components, i.e., courses, assessments, teaching materials, study materials, etc [15] (which can be defined as learning resources). This approach leads to the idea that e-learning courses are created by combining different reusable learning objects.

Therefore, at least three levels may be distinguished within e-learning (Fig.1), i.e.,1) e-learning objects, 2) e-learning courses, and 3) the virtual campus or e-learning program.

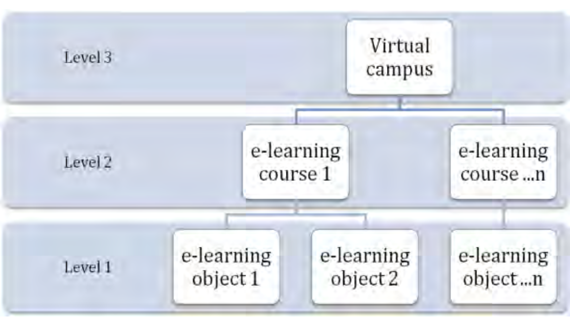


Fig. 1. Levels of development of virtual campus

III. Virtual Campus

A. Learning Objects of the Virtual Campus

We have created, developed and applied various learning objects for EVICAB. These include video lectures, e-book, a virtual discussion system, online quizzes and exercises, lecture notes, animations, virtual models and simulations, Internet exams, lab work and links, the virtual learning environment, i.e., Moodle and a video conferencing approach. Preliminary metadata has been also created.

We consider these learning objects to be level 1. Several of them, i.e., the video lectures and the virtual learning environment could be considered as level 2 when developing an e-learning program, and EVICAB as a whole is level 3.

Levels 1 and 2 learning objects are discussed in the following chapters.

Video Lectures

As a medium for education, video can provide knowledge which is difficult to transfer through text or verbally.

When developing the video lectures we combined and synchronized three elements in one application: presentation slides, video and audio data. The presentation slides were the primary visual channel and carried essential information, such as graphs, relevant illustrations, samples of code, etc. Recorded live lectures were integrated as a secondary visual channel and audio channel (Fig.2). The presentation slides were either in the .JPG file format (converted from .PPT or .PDF documents) or as .CAMREC files. .WMV files were used for the video and audio data. The final format for the video lectures was a Flash .FLV video format, which is popular on the web and can be easily played on any browser with a standard PC/Mac.

The video lectures also include humor, personal examples, discussions, questions and gestures. Employing these techniques in teaching situations reduces the complexity of the content and provides a sense of presence and more cues for understanding the material [16]. The audio channel avoids visual information overload and makes the learning process more effective [17].

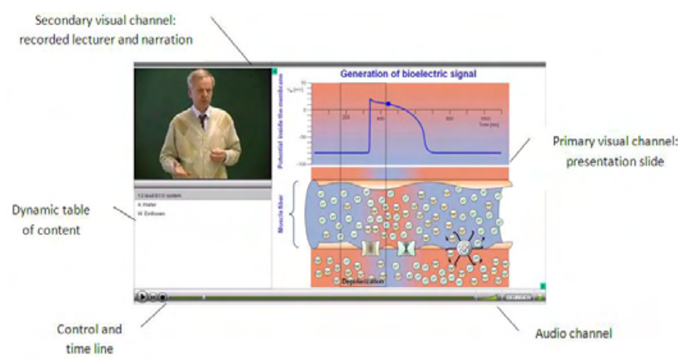


Fig. 2. Elements of video lectures (adopted from EVICAB)

Presentation slides, video and audio data were integrated so that presentation slides take 2/3, recorded live lectures take 1/6, and dynamic table of content takes 1/6 of the frame.

One of the concerns in this study was the application of iPods and media phones for educational purposes. Therefore, in order to avoid the video lectures being tied to one particular type of hardware device, i.e., a PC, and to make them accessible anytime and anywhere, the files were also transformed to MP3, MPEG-4 and 3GP formats, making them compatible with audio players, video players and mobile phones. The files were also accessible with open software, i.e., iTunes and QuickTime player, and could be uploaded to personal media devices.

e-Book

A free access digital book has been available for the Bioelectromagnetism course. It includes the same content and follows the same structure as the original print publication [18].

The digital book in .HTM format can be read on the Internet, downloaded as a ZIP file to a PC or printed chapter-by chapter on a high-quality printer (Fig. 3).

The content of the digital book is presented as text, figures, tables and equations. It incorporates links to previous and following chapters and to video lectures. The font size can be scaled to improve readability.

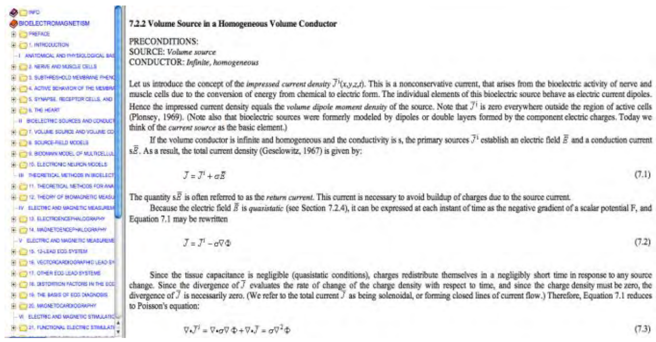


Fig. 3. Page of the e-book on the Internet

One of the advantages of the digital book is that it allows knowledge to be accessible worldwide for anybody who is interested in the field and it supports e-learning.

Virtual Interactivity System

Classroom interactivity is a critical component of teaching and learning [19]. Since video lectures and the e-book lack interactivity and the opportunity to ask questions or express opinions, we implemented a communication and information rating system. The WordPress blog tool and publishing platform [20] was adapted as an asynchronous communication tool (Fig. 4). Users all over the world can leave their comments, messages and suggestions in the system. This rating system was added so that the users could evaluate each lecture, which consists of several video recordings.

Wiki can be used as another way of improving classroom interactivity. This is a group collaboration software tool based on Web server technology [21]. Wiki allows knowledge to be created, shared and managed by anyone (e.g., through reading and updating the content). There are many different wikis, called wiki clones, which can be accessed [22], and downloaded [23], [24] free of charge.

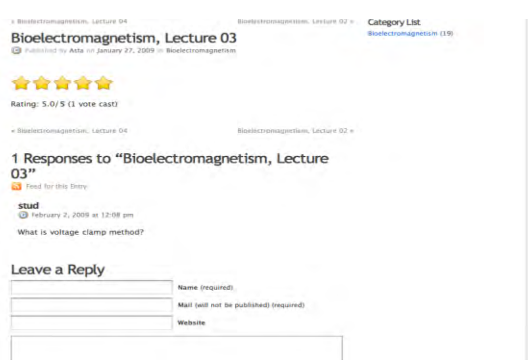


Fig. 4. Discussion system (blog) for virtual students of the course (adopted from EVICAB)

We feel that wiki can facilitate and enhance e-learning. As an example, we found a related page devoted to Biolectromagnetism in a collaborative online encyclopedia [25].

Quizzes and exercises

Online quizzes and individual exercises can replace comparable traditional classroom activities. Such quizzes have been available for virtual students on the Bioelectromagentism course. They include multiple-choice questions based on the course content and provide immediate feedback in the form of the correct answers. Students can take quizzes over and over again until they have acquired the desired knowledge. Quizzes allow the material to be reviewed and offer the students the opportunity to test their knowledge without the intervention of the lecturer.

Individual exercises are also available in the virtual campus. They allow students to reflect on the material. In addition, students can work as a team and present their solutions to an instructor for evaluation.

Lecture notes

Electronic lecture notes are a clear and concise medium provided openly to students via the course website [26]. The e-notes considered here are presented as .PPT presentations or summaries in .PDF, which are available for students to download to their PCs and/ or print. Electronic lecture notes include simple introductions, key concepts, the theoretical foundation and practical examples. They provide an organizational framework, focus attention on the key ideas and suggest cues for retrieval [26]. Students may annotate each slide to include comments and additional information, etc.

Electronic lecture notes are easily reusable learning objects which facilitate active learning by allowing students to be involved in a lecture [26].

Animations

Certain concepts, such as functional anatomy or clinical procedures, can be difficult to explain and understand. Animations can facilitate the explanation and understanding of such concepts by making a story come “alive”, e.g., by showing how the heart contracts and relaxes, how action potential is conducted or how blood flows through the circulatory system, etc.

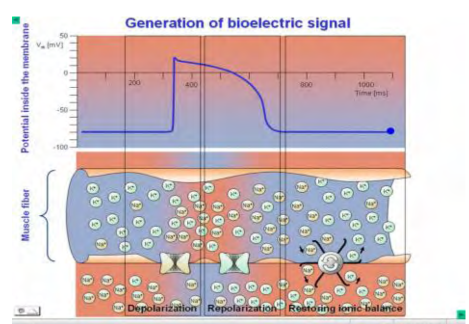


Fig. 5. Animation illustrating generation of bioelectric signal (adopted from video lectures of the course Biolectromagnetism, EVICAB)

Animations on the web are becoming more popular because the software is no longer costly and nor it is as complex or time consuming to learn to use as other types [27].

Several animations have been included in video lectures, in EVICAB (Fig. 5)

Virtual Models and Simulations

Computational modeling and simulations of physiological systems is a practical and non-invasive method of studying how living organisms function.

Several physiological models and simulations were included when developing the video lectures. An example is available in Fig. 6.

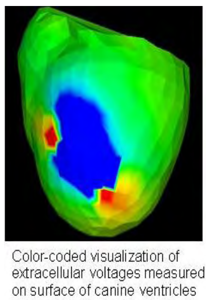


Fig. 6. Simulation – visualization of a human heart (adopted from video lectures of the course Computational Modeling of Cardiovascular Systems, EVICAB)

Internet examination

Internet examination is a new innovation in e-learning [28]. In EVICAB, Internet examination is realized in the following way. The students attend the examination in the computer classroom and their identities are checked (depending on the instructions). When the examination begins, the questions may be opened on the computer. All students may connect to the Internet and use all the available material including the e-book or textbook.

The examinations primarily test students' understanding of the course material and their ability to draw conclusions from it. Therefore, the questions should be of the style: " Why…? " or "For what purpose…?" instead of "What is…" [28]. The Internet examination also makes it possible for the instructor to monitor the progress of the examination regardless of where it is held.

Laboratory works (links)

Deeper understanding and longer retention of what has been learned can be supported by doing experiments. Since real laboratories are not always available for students, interactive experiments using software tools can help students to grasp difficult theoretical concepts or develop certain skills.

A remote online laboratory has been developed for ultrasound medical diagnostics [29]; other examples are available though the tutorial links in EVICAB [9].

Moodle

The Virtual Learning Environment (VLE) is a software system designed to assist teachers in managing educational courses for their students [30].

VLE Moodle [31] has been integrated as an additional element in EVICAB. It has a built-in enrolment system so only those virtual users who have been provided with passwords can access it. The EVICAB Moodle [32] offers simple tools for teachers to create different activities for their students e.g., material presentation, instructions, questionnaires, etc.

Video conferencing

Video conferencing has great potential for learning in higher education, i.e., it allows greater opportunity for dialogue (which facilitates more effective learning) than when the students have to work in isolation [33].

We consider video conferencing as a potential mode of communication between instructors and learners or amongst learners in a virtual environment; particularly for international communication. The instructors can state a certain time when they are available online and the virtual students who have questions can get in touch with them. According to Rixon [33] students vastly prefer video conferencing to other forms of communication in distance education.

B. *Metadata of Learning Objects*

The key issue with using learning objects is the ability to identify them. Therefore descriptive learning objects' metadata has to be created. Learning objects may be described by scale or size (e.g., course, digital asset), content (e.g., multimedia content, instructional content, software and hardware tools), and purpose or intent (e.g., instructional objects, collaborative objects, assessment objects).

The "Curriculum Page" has been created as a preliminary metadata in EVICAB. It lists all the available courses and provides links to all the various materials within them (Fig. 7).

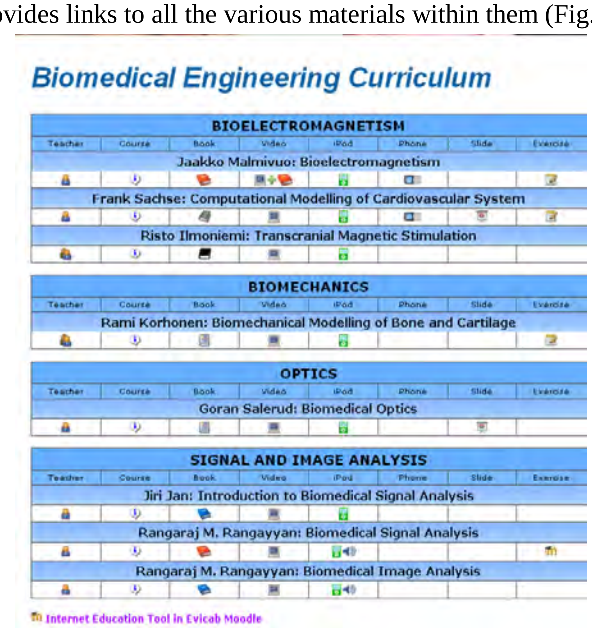


Fig. 7. Biomedical Engineering Curriculum page (adopted from EVICAB)

IV. Discussion

One of the main advantages of virtual education, including e-learning, is accessible education for all students not limited by time, place and pace, etc. E-Learning objects should follow the same principle; they should be accessible with different tools, e.g., computers, iPods and media phones, and available in different formats, e.g., digital or printed.

EVICAB includes different learning objects that can be used by students with various learning styles, e.g., auditory, visual, active or reflective [34]. It is anticipated that when students learn in the way they prefer, they become more interested, motivated and responsible for their own learning process.

Future learning objects should motivate students and provide them with the opportunity to test their knowledge, e.g., creating more intelligent and adaptable learning such as tests for students that automatically assess the student's level of understanding and provide easier or more complicated questions on this basis.

In order to apply learning objects effectively, the following factors should be taken into consideration when they are designed: relevance to the course, usability, cultural appropriateness, infrastructure support, redundancy of access, size of objects and the potential for integration into a learning system [35].

Since it is relatively easy to implement various e-learning objects, it is important to measure whether they have achieved the desired outcomes. This can be tested through providing questionnaires to students and collecting their feedback. Positive answers indicate that learning objects have been designed and applied correctly; negative answers indicate that learning objects should be reconsidered. We have implemented this practice and evaluated the students' attitudes towards learning objects for the virtual campus. The obtained results provide a stimulus for continuing to create, develop and apply high quality and pedagogically valuable learning objects.

V. Conclusions

At least 11 different learning objects have been implemented for the virtual campus of biomedical engineering, EVICAB. The same experience can be extended and applied to any other educational field.

Learning objects are not only fundamental elements of an e-learning course but they also aid educational institutions in establishing new programs based such learning objects.

References

[1] F.T. Lee and B.H. Yeap, "Application of effective teaching and learning methods in engineering education," *micte*, 2005.
[2] M. LaPlaca, W. Newstetter, and A. Yoganathan, "Problem-based learning in biomedical engineering curricula," *Frontiers in Education Conference, 2001. 31st Annual*, 2001, pp. F3E-16-21 vol.2.
[3] P. Schreuders and A. Johnson, "A system approach for bioengineering," *Int.J. Engng Ed*, vol. 15 (4), 1999, pp. 243-248.
[4] T.R. Harris and S.P. Brophy, "Challenge-based instruction in biomedical engineering: A scalable method to increase the efficiency and effectiveness of teaching and learning in biomedical engineering," *Medical Engineering & Physics*, vol. 27, Sep. 2005, pp. 617-624.
[5] J. Giuffrida, "Virtual clinical engineering: from biomedical basics to practical applications," *Bioengineering Conference, 2004. Proceedings of the IEEE 30th Annual Northeast*, 2004, pp. 224-225.
[6] R. Trumbower and J. Enderle, "Virtual instruments in undergraduate biomedical engineering laboratories," *Engineering in Medicine and Biology Magazine, IEEE*, vol. 22, 2003, pp. 101-110.
[7] M.N.K. Boulos, I. Maramba, and S. Wheeler, "Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education," *BMC Medical Education*, vol. 6, 2006, p. 41.
[8] R. Barr, M. Pandy, A. Petrosino, and V. Svihla, "Challenge-based instruction: the VaNTH biomechanics learning modules," *Frontiers in Education, 2005. FIE '05. Proceedings 35th Annual Conference*, 2005, pp. S1G-8.
[9] J. Malmivuo, "EVICAB," *www.evicab.eu*.
[10] W.H. Hodgins, "The future of learning objects," *Proceedings of the 2002 eTEE Conference*, Davos, Switzerland: 2002.
[11] R. McGreal, "Learning objects: a practical definition," *International Journal of Instructional Technology and distance learning*, 2004.
[12] IEEE Learning Technology Standards Committee (LTSC), Working group 12, (WG12), "IEEE WG12: learning object metadata, 1484.12," *http://ltsc.ieee.org/wg12/*, 2005.
[13] M. Sosteric and S. Hesemeier, "When is a learning object not an object: a first step towards a theory of learning objects," *International Review of Research in Open and Distance Learning*, vol. 3, 2002.
[14] R. McGreal, *Online education using learning objects*, Routledge, 2004.
[15] K. Ashley, R. Davis, and E. Pinsent, "Significant properties of e-learning objects (SPeLos)," 2008.
[16] Y. Fritze and Y.T. Nordkvelle, "Comparing lectures: effects of the technological context of the studio," *Education and Information Technologies*, 2003.
[17] R.E. Mayer, *The Cambridge handbook of multimedia learning*, Cambridge University Press, 2005.
[18] J. Malmivuo and R. Plonsey, *Bioelectromagnetism*, New York: Oxford University Press, 1995.
[19] K. Siau, H. Sheng, and F. Nah, "Use of a classroom response system to enhance classroom interactivity," *IEEE Transactions on Education*, vol. 49, 2006, pp. 398-403.
[20] "WordPress," *http://wordpress.org/*.
[21] "Wiki," *http://en.wikipedia.org/wiki/Wiki*.
[22] "Wikispaces," *http://www.wikispaces.com/*.
[23] "Pmwiki," *http://www.pmwiki.org/*.
[24] "Mediawiki," *http://www.mediawiki.org/wiki/MediaWiki*.
[25] "Bioelectromagnetism," *http://en.wikipedia.org/wiki/Bioelectromagnetism*.
[26] M.A. Wirth, "E-notes: using electronic lecture notes to support active learning in computer science," *SIGCSE Bull.*, vol. 35, 2003, pp. 57-60.
[27] G.D. Guttmann, "Animating functional anatomy for the web," *The Anatomical Record*, vol. 261, 2000, pp. 57-63.
[28] J. Malmivuo, K. Lindroos, and J. Nousiainen, "Internet examination - a new tool in e-learning," *Mediterranean conference on medical and biological engineering and computing*, Ljubljana, Slovenia: Springer, 2007, pp. 336-337.
[29] R. Jurkonis, V. Marozas, and A. Lukosevicius, "Ultrasound medical diagnostics laboratory for remote learning in EVICAB campus," *in the Proceedings of International Joint Conference on Computer, Information, and Systems Sciences and Engineering*, USA: 2007.
[30] "Virtual learning environment," *http://en.wikipedia.org/wiki/Virtual_learning_environment*.
[31] "Moodle," *http://moodle.org/*.
[32] "EVICAB Moodle," *http://www.moodle.fi/evicab/moodle/*.
[33] L. Coventry, *Video conferencing in higher education, http://www.agocg.ac.uk/reports/mmedia/video3/video3.pdf*.
[34] R. Felder and L. Silverman, "Learning and teaching styles in engineering education," *Engr. Education*, vol. 78 (7), 1988, pp. 674-681.
[35] S. Smith Nash, "Learning objects, learning object repositories, and learning theory: preliminary best practices for online courses," *Interdisciplinary Journal of Knowledge and Learning Objects*, vol. 1, 2005.

PUBLICATION V

Kybartaite, A., Nousiainen, J., and Malmivuo J. Technology behind video lectures for biomedical engineering. In the *Proceedings of World Congress on Medical Physics and Biomedical Engineering, WC 2009*, Munich, Germany, 7.-12.9.2009, pp. 239-242.

Technology behind Video Lectures for Biomedical Engineering

A. Kybartaite, J. Nousiainen and J. Malmivuo

Department of Biomedical Engineering, Tampere University of Technology, Tampere, Finland

***Abstract*—The main advantage of video lectures is being able to break spatial and temporal constrains when disseminating information. We briefly present the system used for recording and diffusing video lectures over the Internet. The process of recording and diffusing video lectures may be divided into 5 main steps: prepare, record, edit, produce, and share. Video for the educational purposes creates new technical boundaries. Thus, boundaries can be surmounted or diminished by considerate technology analysis and design.**

***Keywords*— Video lectures, record, edit, produce, share**

INTRODUCTION

Nowadays video is one of the most important media for communication and entertainment. Video is a combination of moving images and accompanying sound; these are essential for full understanding and communication. Recording video lectures becomes a common practice also in education. Video as educational media can provide knowledge, which is difficult to achieve through text or verbally. There are many examples [1-5] showing that video lectures become more and more diffused over the Internet. The main advantage of these lectures is being able to break spatial and temporal constrains when disseminating information. There are several different systems in use for recording and diffusing the lectures [6-8]. They are similar in principal, but differ in technical details. How to choose the system which suits your needs and resources?

With this paper we briefly present one of the systems used to record and diffuse video lectures over the Internet.

MATERIALS AND METHODS

The process of recording and diffusing video lectures may be divided into 5 steps (Fig. 1).

Fig. 1 Steps for recording and diffusing video lectures

Prepare

We started by considering predominant factors. What is the purpose of video lectures and who is going to watch them? We came to the conclusion that the purpose of video lectures is to provide possibility to revise and review course materials at any time, place, or pace. The aim of video lectures is to give opportunity for those who do not have access for learning in the classroom. For this reason we focused on recording live video lectures in a traditional classroom environment instead of studio-based environment. We defined three types of potential users of video lectures:

- Students, who study for university degree, seek just in time information, are international students interested in virtual studies, ne(x)t generation students who study mainly outside the classroom, students with work or family commitments, students due to heath problems or disabilities are not able to attend traditional classroom lectures.
- Educators and instructors, who are willing to share and reuse learning materials.
- Industry members, who need focused and immediate scientific information.

Predominant factors boosted further questions. Where video lectures will be posted so that they are accessible for all potential users? What output format is needed? What is maximum file size or bandwidth requirement? What dimensions of video lectures should be? Small video dimensions mean small file size but poor visibility. Larger dimensions

O. Dössel and W.C. Schlegel (Eds.): WC 2009, IFMBE Proceedings 25/XII, pp. 239–242, 2009.
www.springerlink.com

might not fit well for smaller screens without scrolling or scaling the content. Should video lectures include narration, PowerPoint Presentation slides or PDF document, and video stream? How to combine all that data? Unnarrated video lectures do not require setting up audio equipment. Video lectures without secondary video channel ease the whole process. Thus, verbal information and visual cues combined are more effective [9]. What software programs are needed? How to set recording technique and environment? Preliminary solutions were found and tested.

Record

We decided to combine and synchronize three elements in one application: presentation slides, video and audio data. Presentation slides, as primary visual channel, are important elements in the lectures; they carry essential information, e.g., graphs, relevant pictures, samples of code, etc. Recorded live lectures were integrated as secondary visual channel and narration – as audio channel (Fig. 2). Recorded live lectures include humor, personal examples, questioning and gestures. Employing these techniques in teaching situations reduces complexity and supplies more cues for understanding the matter [10]. Audio narration allows avoiding overloading of visual channels and makes the learning process more effective [9].

Presentation slides, video and audio data were integrated using optimization principle; presentation slides take 2/3 of the frame and provide important visual information; recorded live lectures take 1/6 of the frame and provide sense of presence; dynamic and synchronized table of content take 1/6 of the frame and allows to navigate within the material.

In order to record original presentation slides, we used screen capturing technology. It allows recording computer's desktop activity. The recording can be in the form of full motion video, still image, demonstration or program application on lecturer's computer while projecting it to the classroom audience. We recorded slides from lecturer's computer screen while giving the real presentation. This required installing additional software to the computer. Screen capturing software comes in various forms, e.g., as commercial and open software [11]. We selected Camtasia Studio by TechSmith [12]. Screen capture was saved in .camrec file. In this way, data for primary visual channel was obtained.

Sometimes it cannot be possible to capture screen and save its records. In that case .PPT or .PDF documents can be converted to graphic file formats, e.g., JPEG.

In order to record lecture and narration, we used camcorder with AC power supply, wireless microphone system, batteries, cables, headphones and tripod. Recordings were stored to DVD tapes and later transferred to digital .AVI or .WMV files format using basic video creating and editing software, i.e., Windows Movie Maker. It was important to check battery power, white balance, image stabilization, zooming, focusing, sound, lighting, tape, tripod lock-down etc., before video recording. Related problems can damage the whole recording process. Few notes were made in order to achieve higher video and audio quality: camcorder should be directed so that subject's eyes are on or above an imaginary horizontal line drawn one-third of the way down from the top of the frame (a rule of thumb); unnecessary movements of camera should be avoided; lecturer should not walk too much during recording; it is recommended to use wireless microphone, and to avoid movement of cables; a short break should be taken every hour in order to change video tape. More recommendations for video recording are available elsewhere [13].

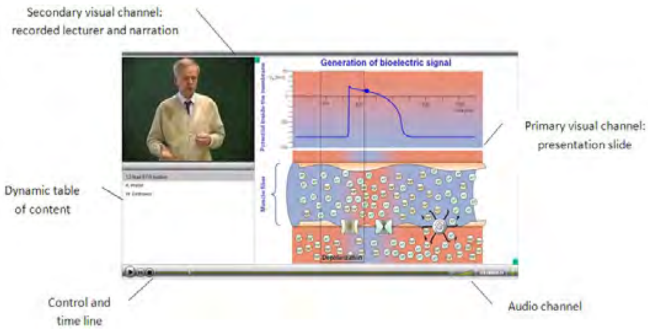


Fig. 2 Elements of video lecture

Edit

Different software can be utilized for editing recorded audio and video data [14-15]. After primary editing, data can be combined and synchronized. We applied Camtasia Studio software. It allows adjusting primary, secondary and audio channels (Fig. 3), i.e., as video, pip and audio tracks. Depending on the quality of data, editing can be quite much time demanding manual process. The process is faster when presentation's slides are available as records, but not in a graphic file format, e.g., JPEG. Lectures can be segmented into time intervals based on the topics. When the lecture is too long and there are too many topics, it distracts the viewer. Also files size becomes too large. The markers for tracking certain slides can be placed on the time line. Software includes more features to enhance video lectures, e.g., dynamic table of content, callouts, captions, zooming, flash quizzes and surveys. More guidance for using software is available elsewhere [12].

Produce

Adobe Flash player is widely distributed multimedia and application player. It uses vector graphics to minimize file size and create files that save bandwidth and loading time. Flash has become a common format for animations and videos embedded into web pages [8]. Flash player is built into recent version browsers or available as plug-in, e.g., in Mozilla Firefox, Opera, Safari, or Internet Explorer browsers. Flash is visible on Macs, Linux and Windows machines. For these reasons we selected .FLV file format for video lectures. Camtasia Studio allows choosing this format for the final output of the production.

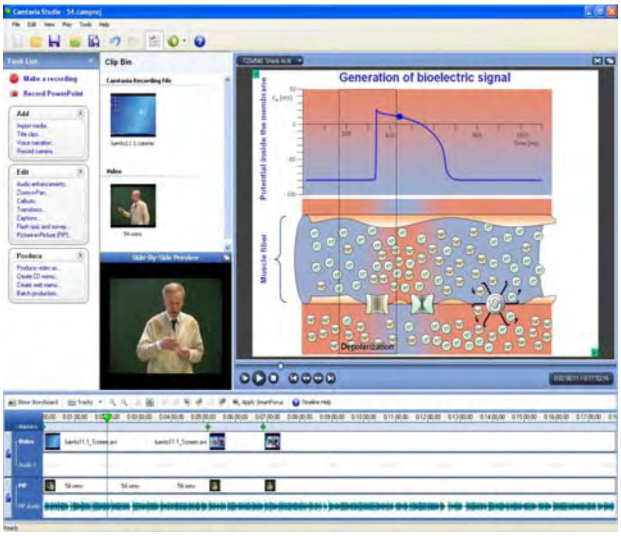


Fig. 3 Editing window for video lecture, Camtasia Studio

The dimensions for video lectures were selected so that they fit different computer screens and do not require scrolling or scaling the content too much (Table 1).

Table 1 Dimensions of video lectures

Elements of video lectures	Dimensions (in pixels, height and width)
Total	1040x595
Primary video channel (slides)	720x540
Secondary video channel (video record)	320x240

The number of pixels of common computer screens usually varies between 640x480 to 2048x1536 pixels [16].

Presets for distributing video lectures on the Internet were selected. In the final production file (of each video lecture) we got Flash file and ten supporting files. The files size averaged from 20 to 100 MB, i.e., about 20 minutes of video lecture is 80 MB. Flash and supporting files were placed on the server in order lectures are accessible via the Internet.

Share

Viewers may not be technology-savy and set-up might hinder their capability to see video lectures. Thus video lectures should put as few technical constrains to the viewers as possible. The minimum bandwidth is 350 Kb/s, thus recommended is 1 Mb/s in order to watch lectures without buffering pauses. A larger bandwidth is becoming more and more available (e.g., DSL technologies), but still this might be true only for certain countries. Using the global broadband speed test [17] we obtained following data e.g., in Finland average available bandwidth is 6,8 MB, in Europe - 5,5 MB, global – 4,8MB, whereas in Asia, e.g., Bangladesh (Dhaka city) - 0,42 MB. Not every browser on every operating system is able to correctly decode video stream. The recommended browser is Mozilla Firefox for video lectures. Another issue to consider is the bandwidth problem on the source site – what will happen to the server if it gets hundreds concurrent requests for videos? We placed video lectures on the university server and did not experience related problems so far. Also it is possible to upload videos on external server [18], [5].

Another way to reduce bandwidth is to reduce video resolution; thus this may end up in low quality that video lectures are not used any more. These choices could be defined at the beginning of video sharing and not modifiable; or dynamic – adjusted in response to the time and needs. We considered how video lectures can be further utilized. Streaming requires constant Internet connection. It is possible to make a downloadable zip file containing lectures to be played later locally on the viewer's computer. Transferring zip file can happen at lower speed but when it is downloaded it can be played multiple times and does not require Internet connection. Another alternative is distributing videos on DVDs.

We produced MPEG-4 files with one visual channel and audio channel, i.e., recorded presentation slides and narration. In order to make video lectures independent of one device, i.e., computer, they can be downloaded to the personal video players [19]. We used iPod players with 320x240 screen resolution to watch video lectures. Power and capability of mobile devices is increasing every day. In addition, we experimented with media-cell- phones by producing and uploading 3GP format files. Nowadays there are different audio and video conversion software, which allows achieving various compatibility files formats [20]. When producing video lectures it should be considered which modality is important and can be used for certain case?

Conclusions

Applying technology advancements we were able to transform traditional lectures to video lectures. Video for the education creates new technical boundaries. Thus, boundaries can be surmounted or diminished by considerate technology analysis and design. We strongly believe that the main focus is the content of the video lectures and different technologies can support it.

References

1. Webcast Berkeley. Available at http://webcast.berkeley.edu/
2. MIT Open Course Ware. Available at http://ocw.mit.edu/OcwWeb/web/courses/av/index.htm
3. Video lectures. Available at http://videolectures.net/
4. Free video lectures. Available at http://freevideolectures.com/
5. Yovisto. Available at http://www.yovisto.com/
6. Dolzani M., Ronchetti M., (2005) "Videostreaming over the Internet to support learning: the LODE system". *WIT Transactions on Informatics and Communication Technologies, v.34, p. 61-65*
7. Hakala I., Impio P., Myllymaki M., Penttila J., (2007) "Video lectures for university teaching". In the proceeding of *VideoFunet* conference, Tampere. Available at http://www.video.funet.fi/conference/2007/abs/Ismo_Hakala_web.pdf
8. Ronchetti M., (2008) . Requirements for videolectures: which system is the best for you? In the proceedings of *World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Chesapeake, VA: AACE, pp. 2192-2199
9. Mayer E.R., (2001) "Multimedia learning". *Cambridge University Press.*
10. Fritze Y., Nordkvelle Y. T., (2003) "Comparing Lectures: Effects of the Technological Context of the Studio". *Education and Information Technologies* 8:4, 327-343, 2003
11. Comparison of screencasting software. Available at *http://en.wikipedia.org/wiki/Comparison_of_screencasting_software*
12. Camtasia Studio by TechSmith. Available at http://www.techsmith.com/camtasia.asp
13. Videomaker. Available at http://www.videomaker.com/
14. List of free software for audio. Available at http://en.wikipedia.org/wiki/Free_audio_software
15. Comparison of video editing software. Available at http://en.wikipedia.org/wiki/Comparison_of_video_editing_software
16. List of common resolutions. Available at http://en.wikipedia.org/wiki/List_of_common_resolutions
17. The global broadband speed test. Available at http://www.speedtest.net/
18. Screencast. Available at http://www.screencast.com/
19. Comparison of portable media players. Available at http://en.wikipedia.org/wiki/Comparison_of_portable_media_players
20. Comparison of container formats. Available at http://en.wikipedia.org/wiki/Comparison_of_container_formats

Author: Asta Kybartaite
Institute: Department of Biomedical Engineering
Street: Korkeakoulunkatu 10
City: Tampere
Country: Finland
Email: asta.kybartaite@tut.fi

PUBLICATION VI

Malmivuo, J., Kybartaite, A., and Nousiainen, J. EVICAB – an open source portal for Internet education. Oral presentation in the World Congress on Medical Physics and Biomedical Engineering, WC 2009, 7.-12.9.2009, Munich, Germany, available at: *www.evicab.eu*, 2009

EVICAB - An Open Source Portal for Internet Education

J.A. Malmivuo[1], A. Kybartaite[1] and J.J. Nousiainen[1]

[1] Department of Biomedical Engineering, Tampere University of Technology, Tampere, Finland

Abstract— **Internet education has become more and more widely accepted format in higher education. There exist several different types of portals with different kind of philosophies to provide educational material on the Internet. Often these portals are composed from a rather large program and the code is not open. We have developed an educational portal which has very simple structure but despite of this it is very versatile and illustrative and easy to use. It is open source and may therefore be easily duplicated for various educational purposes.**

Keywords— **Internet education.**

I. INTRODUCTION

Internet education offers several benefits in higher education. It may be used both as a supporting method for traditional classroom lectures and as an independent means for students who do not have the access to classroom lectures. Because the personal computers and other media devices have become cheaper despite of their fast growing technical performance, all students who want to take higher education courses have sufficient technical facilities to make use of Internet education. Also the Internet connections have improved in speed and there are hardly any countries in the world where Internet education could not be easily reached independently on where the educational material is produced and the server is located.

Many of the portals providing Internet education are, however, rather complex to build up and setting up a new portal often needs special programming skills and large amount of programming labor. This restricts the setting up an education portal to the Internet.

We have developed the portal EVICAB [1], European Virtual Campus for Biomedical Engineering, which is open source and very easy to program. Despite of this it is versatile and easy to use.

II. GENERAL PHILOSOPHY

There exist several different philosophies in the realization of Internet education portals. Here we describe some examples.

Yovisto [2] is a collection of academic videos, where anyone may upload video files. The videos may form a series of videos called Lecture. They are placed in different existing scientific fields. Though the Lectures include videos forming the material for a certain course, there is no information on the credit units and about the possibility to take an exam. The videos are either directly recorded from the lecturing hall presenting the speaker and what he/she draws on blackboard or a set of PowerPoint slides. The videos have, of course, the audio channel as well. Yovisto has free access.

Classroom video collections are provided by several universities like by University of Berkeley [3]. They provide a web site, where a selection of their courses is taken on video directly in the classroom, may be viewed. The videos show the teacher and what he/she presents on the blackboard. The videos are usually not edited and the courses do not provide additional educational material. The videos are free access.

IVIMEDS is a site which provides educational material on physiology and medicine [4]. IVIMEDS does not provide ready made courses. Therefore this material is mainly for help to the teachers to prepare their courses. IVIMEDS needs registration and its annual subscription is considerably high.

Moodle is an example of a very versatile site where the teachers may upload educational material, like lectures and exercises [5]. The students need to register to the platform and therefore its material is not found by general search engines. Moodle gives an excellent possibility to arrange Internet examinations, because the students may upload their answers to it.

EVICAB is an open, free access site. It provides lecturing courses which are selected by the steering group and which are recognized by universities. Therefore other universities may take EVICAB courses to their curriculum and the students may take an exam and thus earn the credit units to their studies. EVICAB also provides additional material supporting the video lectures.

III. EVICAB VIDEO MATERIAL

We believe that a good video material includes both the video on the teacher and the educational material, like PowerPoint slides.

The video on the teacher enhances the feeling of personal contact between the teacher and the student. The teacher's

O. Dössel and W.C. Schlegel. (Eds.): WC 2009, IFMBE Proceedings 25/XII, 2009.
www.springerlink.com

personality and mimicry strengthen the student's concentration to the teaching, which is typically much stronger in the classroom than when following the videos on the computer screen. To optimize the video file size and the requirements for the speed of the Internet connection, the size of this video screen does not necessarily need to be very large. We have used video image of the size less than 400x300 pixels. For the image showing the PowerPoint slides a more accurate image is needed. We have used the size 650x550 pixels.

In addition to the afore mentioned video material, which may be viewed with computer, EVICAB offers the PowerPoint slides also in m4v –format for iPod and in 3gp -format for media phones. The m4v –files may also be viewed with the Cinemizer binoculars produced by Carl Zeiss [6].

The technology for producing the video material is discussed elsewhere [7].

IV. Lectures and supporting material

The EVICAB lectures are at the moment primarily recorded from Graduate Courses and Intensive Courses given in Finland. One course is also recorded in Estonia. The teachers are recognized Finnish and international experts in their discipline. We have been glad to note, that the teachers appreciate EVICAB and the visibility which it gives to their teaching so high, that they have been glad to allow the video recording and their publishing free of charge. This is a fundamental precondition in making EVICAB free access.

EVICAB courses are selected by the steering committee and there is no possibility for free uploading of courses. Only courses which are recognized by a university are accepted. This ensures the high quality of the educational material. Courses may also be proposed by teachers outside the EVICAB consortium.

In addition to the videos, EVICAB portal offers various kind of material supporting the video lectures. These include eg. information on the teachers, the course and the book. If the book is available on the Internet it may be displayed simultaneously with the video lecture. Exercises are also provided. A collection of publications and lectures given on EVICAB in various conferences and other deliverables are also included.

The courses are also provided with a facility for the students to give rating on the quality of each lecture and giving comments and possible supporting information on the lecture topic. This is made real with the commenting platform provided by World Press [8].

EVICAB also provides a collection of links to similar educational material available on the Internet.

V. Accessibility and statistics

Because EVICAB is on an open Internet portal and its use does not need registration, the search engines find it easily. EVICAB has reached world wide interest and it is visited monthly over 1.500 times with over 20.000 hits from all around the world.

We have implemented the follow up of the visits with three different statistics program which allow us to carefully follow the number of visits to each page of the site and the country of the visitors [9]. The demographic information is also displayed graphically on world map [10].

The statistics is very informative and serves as the basis for developing the EVICAB. It indicates what lecturing courses are more popular and therefore, in which areas more courses should be offered. In this issue also the aforementioned commenting and rating facility is for help.

The use of EVICAB by the students and quality of the lectures are also evaluated with questionnaires among the students of those EVICAB courses which are also given as traditional lecturing courses.

VI. conclusions

Internet education is coming more and more important format in higher education. Its wider application needs an open source and simple portal which may be made real with small amount of labor and without high expertise in Internet programming. We have developed the EVICAB portal which fills these requirements. Its frequent and worldwide use has shown that we have succeeded in this task.

References

1. www.evicab.eu
2. www.yovisto.com
3. webcast.berkeley.edu
4. www.ivimeds.com
5. www.moodle.org
6. www.zeiss.com/cinemizer
7. A. Kybartaite, J. Nousiainen and J. Malmivuo: Technology behind Video Lectures for Biomedical Engineering, 2009, (submitted).
8. wordpress.org
9. www.webstat.com
10. www.clustrmaps.com

Author: Jaakko Malmivuo
Institute: Tampere University of Technology
Street: Korkeakoulunkatu 3
City: 33720 Tampere
Country: Finland
Email: jaakko.malmivuo@tut.fi

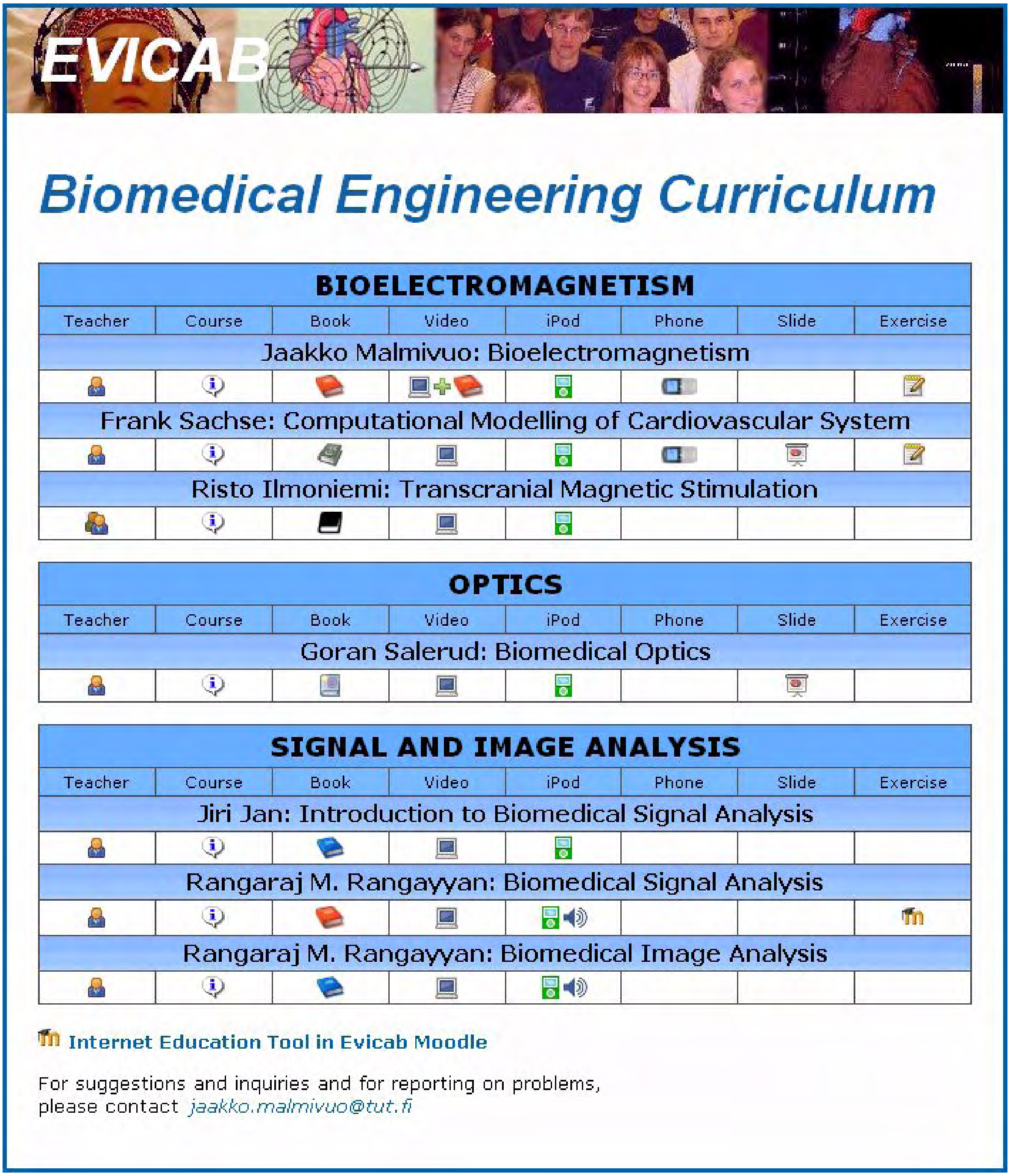


Fig. 1 EVICAB curriculum page at www.evicab.eu

PUBLICATION VII

Malmivuo, J., Kybartaite, A., and Nousiainen, J. EVICAB – biomedical engineering program on the Internet including video files for iPod. In the *Proceedings of the 4th European Conference of the International Federation for Medical and Biological Engineering*, Antwerp, Belgium, 23.-27.11.2008, pp. 2738-2741.

EVICAB - Biomedical Engineering Program on the Internet including Video Files for iPod

J.A. Malmivuo, A. Kybartaite and J.J. Nousiainen

Department of Biomedical Engineering, Tampere University of Technology, Tampere, Finland

Abstract — **Internet is more and more used as an educational tool. We have developed the EVICAB platform which provides a curriculum in Biomedical Engineering. EVICAB includes the educational material in various formats eg. lecture videos, lecture slides, textbook, exercises and examination. The video material is available in various formats to be viewed on the PC, iPod and media phones. EVICAB offers for the users the possibility to submit additional information and comments. It also includes rating of the educational material. Its use is free and it is available worldwide.**

Keywords — **Biomedical engineering, Internet education, www.evicab.eu**

I. Introduction

The most modern and advanced method in education and student administration is the use of Internet. The use of Internet makes the geographical distances to disappear and allows the studying at a time which is most convenient to the student.

Biomedical Engineering is needed all around the world and globalization encourages the students to mobility between universities. It is important that education in Biomedical Engineering is harmonized to facilitate the mobility. The BIOMEDEA project facilitates this within the study programs in European universities. All this gives strong reasons to develop an education program on the Internet.

This is the basis for the project: European Virtual Campus for Biomedical Engineering – EVICAB. It was funded by the European Commission Education and Training for 2006-2007.

EVICAB offers high-quality courses prepared by the best international teachers. The courses include lecture videos and associated lecture slides. The courses are also associated with additional teaching material like full textbooks, exercises, laboratory exercises etc.

All courses offered by EVICAB are recognized by at least one university in the European Union. Thus it is easy for any other university in the EU to include EVICAB courses to their curriculum.

Because the teaching material in EVICAB is available free of charge and because it can be used via Internet form anywhere in the world, the BME program provided by the EVICAB is available for worldwide use.

EVICAB uses the Wiki-idea but is more strongly controlled by an Administrative Board. This ensures that the teaching material provided by the experts is of high quality and cannot be changed by anyone else than the author. In addition to the primary teaching material, the courses have windows with free access. These are used for providing additional teaching material by the users of EVICAB. In addition to helping the students, this Wiki material may be utilized by the course author for improving the course.

The teaching material for EVICAB is provided by the best experts free of charge. The benefit from this for the teacher is that his/her reputation as an expert will be strengthened worldwide and this will support his/her career as pedagogue and scientist.

Associated to the EVICAB education there is also developed a method for Internet examinations. This will further strengthen the worldwide use of EVICAB because the geographical location of the students and the teachers does not play any role anymore.

www.evicab.eu

II. Evicab project

The objective of the project is to develop, build up and evaluate sustainable, dynamical solutions for virtual mobility and e-learning that, according to the Bologna process,

- Mutually support the harmonization of the European higher education programs,
- Improve the quality of and comparability between the programs, and
- Advance the post-graduate studies, qualification and certification. These practices will be developed, piloted and evaluated in the field of biomedical engineering and medical physics.

Important goal is that these approaches and mechanisms for virtual e-learning can be extended and transferred from this project also to other disciplines to promote virtual

J. Vander Sloten, P. Verdonck, M. Nyssen, J. Haueisen (Eds.): ECIFMBE 2008, IFMBE Proceedings 22, pp. 2738–2741, 2008

student and teacher mobility and credit transfer between European universities.

III. EVICAB CONSORTIUM

EVICAB is coordinated by the EVICAB consortium. Professor Jaakko Malmivuo at Tampere University of Technology serves as Director of the project and Assistant Professor Juha Nousiainen as coordinator. The consortium has partners in Finland, Sweden, Estonia, Lithuania and Czech Republic. EVICAB also co-operates with the BIOMEDEA project. This is important because harmonization ensures wide application of the educational material.

EVICAB welcomes interested institutes to join as associate partners. We hope that the associate partners actively participate in producing teaching material to EVICAB.

IV. IDEA OF EVICAB

The fundamental idea of the EVICAB is that it offers an open platform for Biomedical Engineering curriculum on the Internet. The openness means the open access to and free right to use the resources of the EVICAB, and an open possibility for all experts in the field to contribute to the development of the content of the virtual curriculum.

Teachers, who are experienced and recognized experts in their field, are encouraged to submit full e-courses, course modules and other teaching material to EVICAB. The material may include many different formats like video lectures, PowerPoint slides, pdf-files, Word files etc.

EVICAB is not a university. The course and student administrations continue in the universities as usual: The teacher, responsible of the course/study program, may select from EVICAB courses for the BME curriculum of the university. The students study the courses either as ordinary lecturing course with the EVICAB material supporting the lectures or the course may be partially or solely studied from EVICAB. The students, or anyone even outside the university, may study EVICAB courses to add their competence in Biomedical Engineering. Thus EVICAB is important also for the persons in the working life to improving their professional competence.

The EVICAB has an Administrative Board which administers the EVICAB curriculum. The board accepts courses of sufficient scientific, pedagogical and technical quality. The board may also invite experts to provide course material to the EVICAB. Courses which apparently are of low quality, either out of date, lower quality than competing courses and not appreciated by the users of the EVICAB will be deleted. Active feedback from the users of EVICAB, both teachers and students, is essential. All this will be realized by utilizing a dynamical quality assurance system.

V. IMPACT OF EVICAB ON E-LEARNING

In its completed form, EVICAB will have strong impact on all main levels of the education process:

For students it will provide virtual mobility as a complementary, preparatory, or even substitutive option for physical mobility. The increased number on e-courses for distance learning will give higher variety of qualified studies and degrees.

Teachers will substantially benefit from the open resources, teaching materials and e-courses available through the EVICAB. The support provided for design and development, as well as the good practices and high-quality e-courses will motivate and spur the teachers in the e-course development.

EVICAB will contribute to the harmonization process of BME curricula in Europe in co-operation with BIOMEDEA and will improve the quality of the curricula. Finally, the solutions and models developed for building the virtual BME curriculum can be applied to other disciplines.

VI. FORMAT OF THE EDUCATIONAL MATERIAL

The basic format of the educational material on the Internet includes a larger window for the lecture slides and a smaller window for a video on the teacher. The sound track is, of course, also included. The lecture videos may be easily browsed back and forth for the student to repeat the difficult issues or to skip less interesting issues in the lecture.

The EVICAB courses include also other educational material than the videos. These include: information on the teacher and the course, course book, and exercises. One of the courses, Bioelectromagnetism, displays simultaneously the corresponding location of the book below the video.

The lectures will have a discussion forum for the students to make comments or add relevant links and material.

The lectures will also have a rating system for giving overall rating and for rating the technical and/or pedagogical quality.

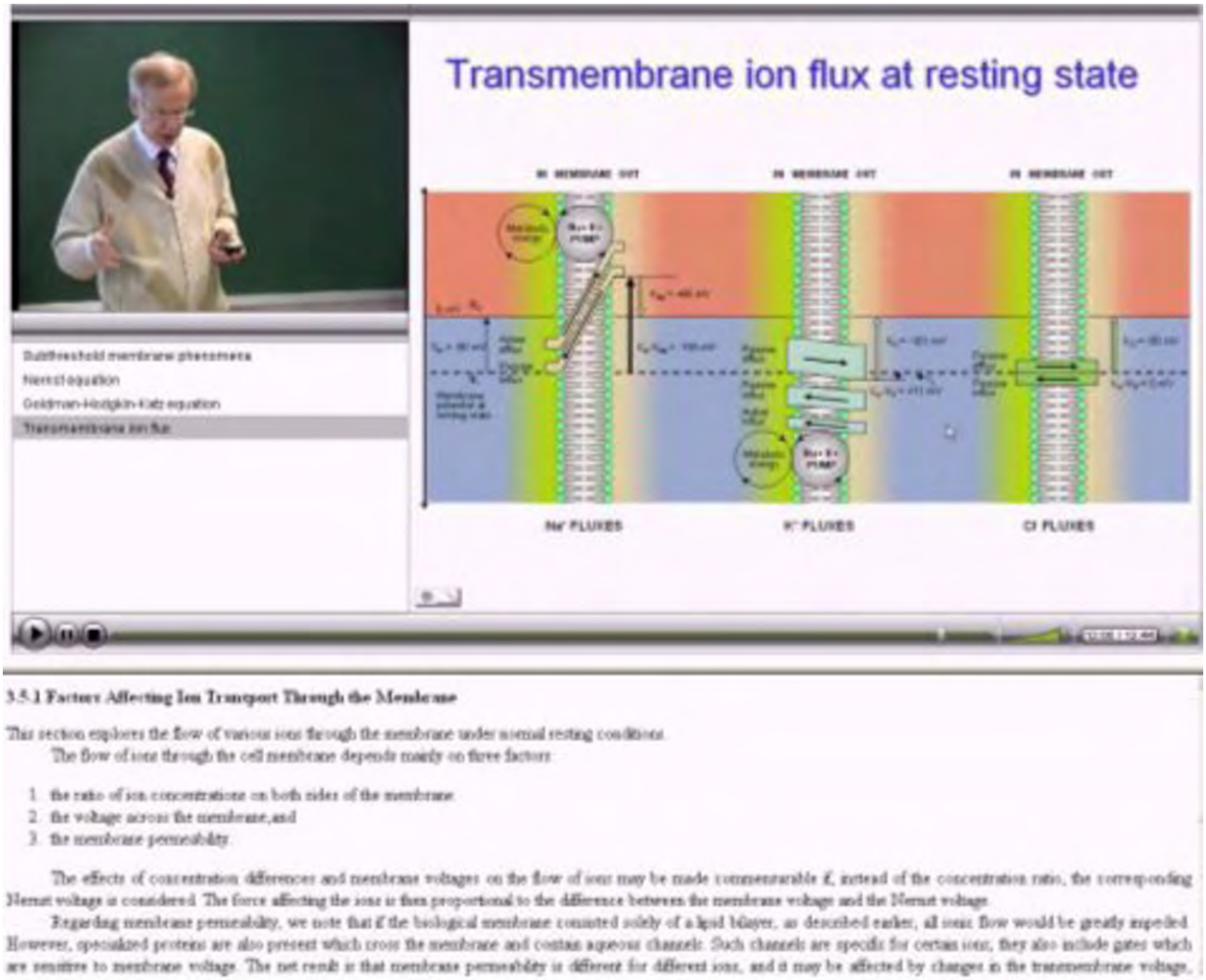


Fig. 1. Example of the lecture video with a larger window for the slides and a smaller window for the lecturer video. Below is a window for the textbook material of the lecture. The windows may be resized and the textbook material may be freely scrolled.

VII. Mobile course material

One of the key issues in the EVICAB is to reach the students anywhere and anytime. The learning process should not be dependent on the location of the student. Internet based material supports this idea and hence all the educational resources are provided in the EVICAB platform on the Internet.

Not only is the Internet used for media for learning process but also portable devices such as iPod and mobile phones can be used. In EVICAB project these media are supported. The video lecture in these formats may be downloaded from EVICAB web page and uploaded to the iPod or media phone. Because of the limited size of the image in these devices, these files include only the PowerPoint slides and the sound, not the video image of the lecturer. A new interesting application is the Cinemizer produced by Zeiss. It includes two video images in front of special spectacles which are connected to iPod. They also include earphones fixed to the frames of the Cinemizer. Cinemizer provides a “hands/free” binocular (though not stereoscopic) observation of the videos.

Students may choose the best media for his or her current lifestyle; busy student may, for instance, watch the lecture videos in a bus on the way to or from university.

VIII. INTERNET EXAMINATION

Another successful innovation and application in our e-learning activities has been the Internet examination.

In the Internet examination the students make the exam in a computer class. This may be performed simultaneously in several universities. Therefore the students do not need to travel to the location there the course was given.

The students open the Moodle program at the time of the examination and find the examination questions from there. We usually allow the students to use all the material available on the Internet. This requires that instead of asking "What is ..." the examination questions shall be formulated so that they indicate that the student has understood the topic and is able to apply this information. The only thing which is not allowed is communication with another person via e-mail etc. during the examination.

IX. WHY TO PROVIDE COURSES TO EVICAB?

EVICAB is an important teaching and learning method only if it is available free of charge and worldwide. As a consequence, the learning material should be provided free of charge.

Why experienced and competent teachers should provide such material without charge and without receiving royalties? Acceptance of a course by EVICAB will be a certificate for quality. Worldwide distribution to all university students will give exceptional publicity for the author and his/her university. All this will facilitate the sales of traditional teaching material produced by the course author. This will also attract international students from other countries all over the world to apply to the home university of the material author. We already have experience which has proven these issues to be realistic.

The Internet has dramatically changed the distribution of information. Distribution is worldwide, real time and free of delivery costs. The technology also supports wide variety of attractive presentation modalities. All this ensures wide audience and publicity for the material on the Internet. For instance, the Wikipedia dictionary serves as a successful example of this new era of information delivery. On the basis of this publicity it is possible to create markets also for traditional printed educational material. In addition the EVICAB will provide the platform for all courses free of charge. Pedagogical evaluation and technical support for course design are also provided in request. This will ensure the high quality and up to date virtual learning environment.

X. CONCLUSION

In the future, the teaching and learning will mainly be based on the Internet. The ideas and the technology of EVICAB are not limited only for application on Biomedical Engineering but it may be applied to all fields and levels of education. EVICAB will be the forerunner and show the way to more efficient and high quality education

ACKNOWLEDGMENT

This work has been supported by the European Commission Education and Training. Ministry of Education in Finland, Academy of Finland and the Ragnar Granit Foundation.

The address of the corresponding author:

Author: Jaakko Malmivuo, Prof.
Institute: Dept of Biomedical Engineering
Tampere University of Technology
Street: Korkeakoulunkatu 6
City: 33720 Tampere
Country: Finland
Email: jaakko.malmivuo@tut.fi

PUBLICATION VIII

Lugmayr, A., Hornsby, A. Golebiowski, P., Jumisko-Pyykkö, S., Ubis, F., Reyman, S., Bruns, V., Kybartaite, A., Kauren, J., and Matthes, D. E=MC2+1: A fully digital, collaborative, high-definition (HD) production from scene to screen. *Computers in Entertainment (CIE)*, vol. 6, no. 2, NY, USA, The ACM Digital Library, p. 33, 2008.

http://doi.acm.org/10.1145/1371216.1371229

E = MC² + 1: A FULLY DIGITAL, COLLABORATIVE, HIGH-DEFINITION (HD) PRODUCTION FROM SCENE TO SCREEN

ARTUR LUGMAYR, HORNSBY ADRIAN, PIOTR GOLEBIOWSKI, SATU JUMISKO-PYYKKO, FERNANDO UBIS, SIMON REYMANN, VOLKER BRUNS, ASTA KYBARTAITE, JARKKO KAURANEN, AND DIRK MATTHES

Tampere University of Technology, NAMU - New AMbient MUltimedia Lab., Finland

---

This article presents a unique course for students, the course took place at the Tampere University of Technology (TUT) in the NAMU - New AMbient MUltimedia research group. The basic idea was to create a five-minute production involving all the new technology available to the modern film-maker. We want to prove that even a non-experienced team of film-makers are capable of creating a short HD film with (almost) commonly available equipment. A full high-definition (HD) digital workflow was undertaken - from scene to screen. In each production step, new technologies and approaches were tested to explore the world of digital film-making. In pre-production the movie-script was written collaboratively with Wiki tools. The participants' experience was evaluated, and the results are presented in this article. In production we focused on HD methods to create content and applied the Material eXchange Format (MXF) to handle metadata in production; the final movie was distributed via typical television channels, such as DVB-T, IP-TV, and DVB-H. The experimental results are presented in this article as well. In this article we present our experience in terms of technology, introduce a learning-by-doing concept during course development, and give a complete analysis of a full digital HD workflow.

Categories and Subject Descriptors: J.5 [**Computer Applications**]: Arts and Humanities; K.3.1 [**Computers in Education**]: Computer Uses in Education-*Collaborative learning*; *Computer-assisted instruction*

General Terms: Experimentation, Human Factors

ACM Reference Format:

Lugmayr, A., Adrian, H., Golebiowski, P., Jumisko-Pyykko, S., Ubis, F., Reymann, S., Bruns, V., Kybartaite, A., Kauranen, J., and Mathhes, D. 2008. E=MC² + 1: A fully digital, collaborative, high-definition (HD) production from scene to screen. *Comput. Entertain.*, 6, 2, Article 26 (July 2008), 32 pages. DOI = 10.1145/1371216.1371229 http://doi.acm.org/10.1145/1371216.1371229

---

1. INTRODUCTION

Traditionally, media content creation was always reserved for professional studios, due to the necessity for the specialized and expensive equipment and the artistic skills for such an undertaking. Since the explosion of the digital world, media creation has become more

---

This work was supported by the Academy of Finland, project 213462 (Finnish Centre of Excellence Program (2006 - 2011) as well as by the EU IST ENTHRONE2 project.
Authors' address: Tampere University of Technology, NAMU - New AMbient MUltimedia Lab., Tampere, Finland. email: fistname.lastname@tut.fi, web: www.cs.tut.fi/sgn/namu

and more accessible to the general public. The YouTube [http://www.youtube.com/] phenomenon is a very good example: people just grab a digital camcorder, setup a mini home studio and start publishing their material themselves. Still, nowadays very few people actually use the full potential of digital technology: first, there is a lack of understanding of the process of artistic creation; second, the technology is available to consumers, but understanding the techniques required to use its full potential is poor. Artists might argue that technology is only a tool to realize the artistic masterpiece. Nevertheless, to be able to tell a story with a fully digitally produced movie, the underlying technologies have to be well understood.

The obvious convergence between artistic movie creation, common IT technology, and the Internet makes the life of the modern film-maker even harder. Nevertheless, only by understanding the underlying techniques and methods of this technology enables the modern film-maker to make production cheaper, get greater audience exposure, and create a never-before seen story world for the consumer. Film-making is still about telling stories and immersing the consumer in a fictive world - only the underlying technology to create this fictive world has changed. The possibilities in the says that a single story can be told by utilizing digital film-making technology are becoming infinite. However, exploration by artists of this technology is still in its infancy, but is proceeding rapidly. This trend can be seen in the advances made by animated films during the recent decade. Nowadays many different digital media techniques, ranging from graphics art technology, 3D content production for TV and film, large-scale content management systems for new media, computer game development, network design techniques for high-demand media systems, systems for new media solutions, software design methods, media technology are available to tell a story in many new ways. And this exactly is the content of this article.

1.1 Context and Novelties of this Work

In this article, the course "Modern Techniques for Producing Media Content" is described from the students' as well as the teacher's point of view. The course was offer-

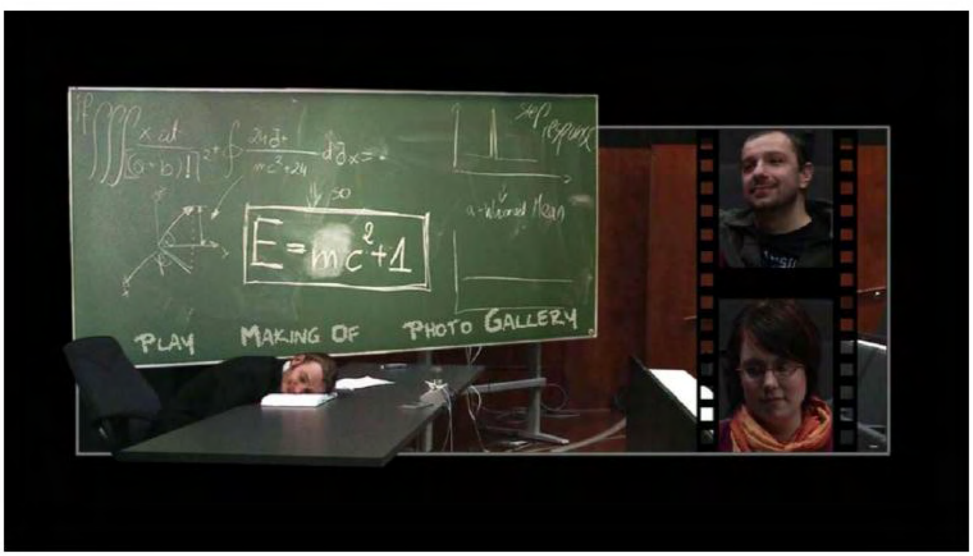


Fig. 1. DVD menu of E=MC2+1.

ed by NAMU (New AMbient MUltiemdia Lab. [www.cs.tut.fi/sgn/namu]) at the Tampere University of Technology (TUT). The goal of this course was to create a short high-definition (HD) movie by applying many new digital production paradigms. The course was intended for non-professional film-makers, that is, for people with no previous experience in film-making. The digital production process involved, besides many typical aspects in film production (namely, pre-production, production, post-production, distribution, and data management processes), many new methods in digital film production.

In this course, the following experiments and techniques were applied during production:

- implementation of a full digital workflow - from scene to screen;
- collaborative script-writing with Wiki tools;
- evaluation of user experience with collaborative script-writing;
- high-definition (HD) digital production workflow;
- introduction of learn-by-doing concept during course development;
- partial application of the Material eXchange Format (MXF) in production;
- analysis of improvements due to full digital workflow; and
- research of film-media technology.

1.2 The Movie E=MC2+1

Our short film shows a typical day in the life of some students: it is a humorous presentation, which shows students partying with their teacher the day before a lecture. Everyone is there - the nerd, the cool guy, and the Latin lover. And everything is there - fun, alcohol, jealousy, and love. But was it just a normal student party?

Production Team: Director: Piotr Golebiowski, Assistant Director: Teemu Karjalainen, Actors: Simon Reyman, Volker Bruns, Satu Jumisko-Pyykko, Carol Rus, Piotr Golebiowski, Marjo Meija, Alberto de Martino, Antonietta Pepe, Dirk Matthes, Linda Franke, Judith Radau, among others, Cinematographer: Jarkko Kauranen, Camera Operator: Adrian Hornsby, Camera Assistant: Asta Kybartaite, Lights: Alberto de Martino, Makeup Artists: Satu Jumisko-Pyykko, Sound: Antoinetta Pepe, Boom: Fernando Ubis, Distribution: Mikko Oksanen, Stills: Carol Rus, Production Assistants: Juan Luis Garcia, Dirk Mathes, Executive Producer: Artur Lugmayr

2. RELATED WORK

Comprehensive work dealing with workflow management for fully digital productions is rather scarce. Nevertheless there are a few such that cover different parts of the entire workflow, such as asset management and metadata [Lugmayr et al. 2004; Mauthe and Thomas 2004]; the TV production side [Millerson 1999]; and the artistic side [Bordwell and Thompson 1997]. Practical studies of a file-based 4:4:4 HD production project in Finland was presented in Golebiowski [2006]; Golebiowski et al. [2007]; and Lugmayr [2006]. Other related work is cited in the course of this article.

3. CAPTURE IN HIGH-DEFINITION (HD)

Capture in movie making is currently shifting from its analogue form to a digital counterpart. In principle, we have to distinguish between video and film capture. Film capture is based on a chemical analogue process. Video is digital, and has been applied for television, but now increasingly is entering the world of film. While many still argue

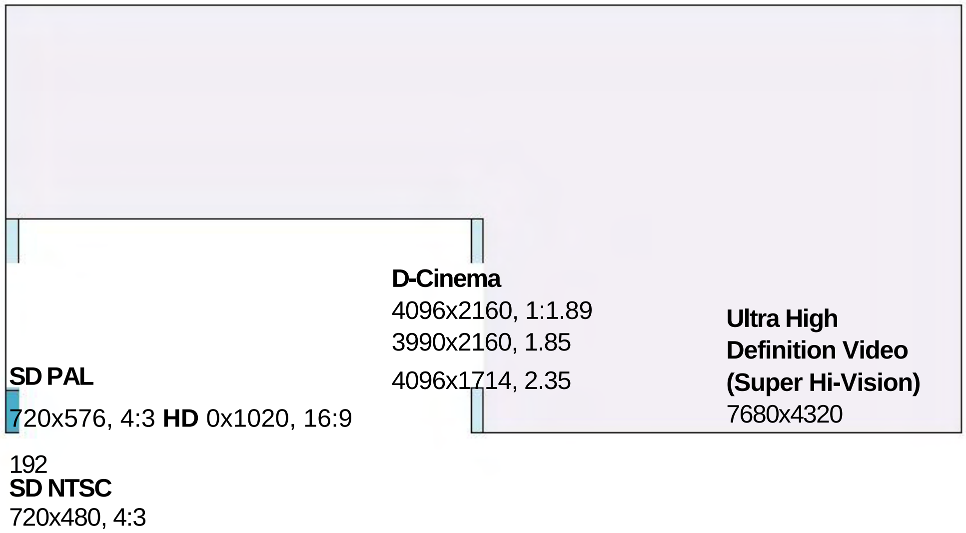


Fig.2.Various high-definition (HD) resolutions, ranging from television to digital cinema.

about quality issues, the full digitalization of the film medium is a matter of a few years. For a long time, video was rejected by film-makers as being non-artistic, low quality, and cheap; but nowadays video is one of the most important media for communication and entertainment, due to progress in digital electronics and computing

Video was initially recorded and stored in analogue form, due to progress in digital electronic and computing a brand new world has opened up for video, i.e., digital video. Since the late 1980's, video compression has became a very important research area and has led to many different applications in storage, transmission, and visualization of digital content (e.g., DVD's, IP-TV, digital television (DVB), video conferencing).

Nowadays there is much confusion about the key parameters in HD (see **Fig.2** for an overview of various HD resolutions). In the following, we present the relevant key parameters for a full production workflow:

- *HD resolution*. We have to distinguish between different HD formats used in different stages of a production (see **Fig.2**). The consumer mostly comes in touch with the television formats, which come in a resolution of 1920x1080 or 1280x720. The first one has 2.25 times more pixels than the second, affecting encoding time, decoding speed, and storage space requirements. However, digital cinema (D-cinema) provides even higher resolutions, going up to 4096x2160 pixels.
- *Interlaced/progressive*. The different video standards offer two different types of frames for capture: progressive or interlaced. Progressive standards capture the full range of pixels in one frame. Interlaced standards work as a common analogue to television sets, and only every second line is captured. Choosing between them impacts the required storage space, decoding/encoding times, and compression ratios. Progressive is better than interlaced in term of decoding time and compression ratio.
- *Frame-rate.* Relevant HD frame rates are 24, 25, 30, or 60 fps. Frame rates also have an important impact on performance. The higher the frame rate, the higher the required bandwidth and processing power.

- *Color information.* Color information can be in RGB or YUV (Y'CbCr) values. RGB is mostly used in the IT domain on PC screens or for storing visual content. However, during production the YUV model is frequently used. The Y'CbCr color space can take advantage of the fact that the human eye is more sensitive to brightness in green tones, less sensitive in red tones, and least sensitive in blue tones. Depending on whether the color is sampled at 8 bits, 10 bits, or even 12 bits per sample per component, bandwidth for each component can vary a lot. With HD formats, the values of Y, Cb, and Cr are displayed differently than with other standard definitions (SD). Indeed, HD formats use the 709 color format instead of the Consultative Committee for International Radio (CCIR) 601 color format.
- *Bit rate.* Video formats have either 8-bit per channel (256 steps from black to white), 10-bit per color channel (1024 steps), or even 12-bit per color channel (4096). This affects video quality during editing or post-production. The bit-rate is highly affected by the sampling rate of the video; 4:4:4 and 4:2:0 are the most commonly used in digital film-making. Typically, 4:4:4 is used inside a production environment, and means that the different color channels are sampled at the same rate; 4:2:0 is mostly used for play-out and sub-samples the different color channels at a lower rate, leading to smaller data rates.

4. COLLABORATIVE PREPRODUCTION BY APPLYING WIKI TOOLS

In this section, conservative or traditional script-writing is briefly discussed. This section presents the process of collaborative script writing. As summary, the results of a user evaluation of the anonymous online poll are presented as well

4.1 Conservative Script-Writing

In professional film production, the first and most obvious phase is pre-production. During this phase the scope and preparation of all essential elements of the film are taking place. This includes writing the screenplay, breaking down the script, creating production plans, defining schedules and film-budgets (see Millerson [1999]). However, more and more alternative production methods, emphasizing online collaboration, are integrated into this phase of production. In this section, we describe the experiences with collaborative script-writing with Wiki tools during the course. Wiki tools were applied to convey the general idea of collaborative script-writing to students.

Thomas Edison said "Genius is 1% inspiration and 99 % perspiration". In other words, a genius is a talented person who has done all his or her homework. This applies well to script-writing. Script-writing is a complex task and requires much experience, passion, and creativity. Traditionally, one person creates a script based on a basic story idea. And to be successful, and eventually start making money, requires years of training and time to get a script right.

Table I. Overview of Various HD Formats and Typical Parameters

Resolution	frame-rate	Sampling rate	Data-rate (Mbps)	Storage (GB/hour)	Bit depth
1280x720	24p	4:2:0	332	146	10
	60p	4:2:0	818	364	10
1920x1080	24p	4:2:0	746	328	10
	60i	4:2:0	932	410	10

Every media demands certain rules that writers must comply with to get a message to an audience. For example, writing for electronic media enables the reader to go back and re-read a sentence that may not have been well understood. In a film production, however, the meaning is lost if it is not grasped immediately by the audience. In a cinema exhibition, there is no way to play it again: the viewer would be distracted by the ongoing content while trying to figure out what was meant. So writing for the ear is totally different from writing for the eye [CyberCollege 2007].

Despite what was previously stated, conservative script-writing can be a collaborative approach as well. Discussions, sparking ideas from others or giving the script for friends or colleges to read can often lead to new developments in the story. The Internet allows new models for script-writing by involving the community of the net. Still, to produce a really well-written script, Internet script-writers must also follow certain guidelines and to create an acceptable format (i.e., font-size, punctuation, style). One simple example is the use of three dots "…" to indicate a pause. There are several forums and web communities that discuss these style issues (see, e.g., Academy of Motion Picture Arts and Sciences [http://www.oscars.org/]). In general, there is no fixed standard or anything similar for the process of script-writing, since it is and always will be a creative process of either one or multiple persons.

The approach described in this article is to create a script by involving multiple students via the Internet - especially Wiki - technology and was a challenge for the duration of the course. In terms of management and team-building collaborative scriptwriting requires a well-organized framework in which contributing writers can easily introduce their ideas, refine them, and let their imagination flow.

4.2 Collaborative Scriptwriting with Wiki Tools

New technologies, such as wikis, blogs, and podcasting are challenging the traditional way of collaboration. Community-driven services are gaining influence on relations between producers and consumers. Indeed, with a system like Wiki, readers can instantly become writers and influence the story.

The idea of using a Wiki-based system for collaborative script-writing emerged during the course. After very long discussions we had lots of brilliant ideas, but could not merge them or settle on an agreement. We tried to come up with a system that could allow anybody in the course to write and defend their ideas at anytime of the day. But that the style of the collaborative script should still be the style of a professional movie script. We soon came up with the idea of using Wikis to be more flexible in writing the script. We surmised that Wiki tools would be more flexible than print versions or circulating digital documents, as the course participants could just read, think, and insert their thoughts, and make them available to everyone. Thus, people did not have to wait until the next face-to-face meeting to debate the ideas or circulate digital documents containing many un-viewable revisions. Still, the success of collaborative script-writing using a Wiki system relies on the participation of the users, their dedication to developing the script itself, and the sense of digital community.

In the course, both traditional and collaborative script-writing methods, as described in this section, were taught during a single teaching session. Afterwards, the students gathered in groups of two or three to brainstorm ideas and topics for the script in a limited amount of time. Next, the individual groups had to select one of their ideas and further elaborate on it. At the end of this phase, a member of each group gave a brief presentation of the idea in front of the class. At this point, the stories had clearly not yet been worked out very thoroughly, they consisted of a basic idea that the final script could

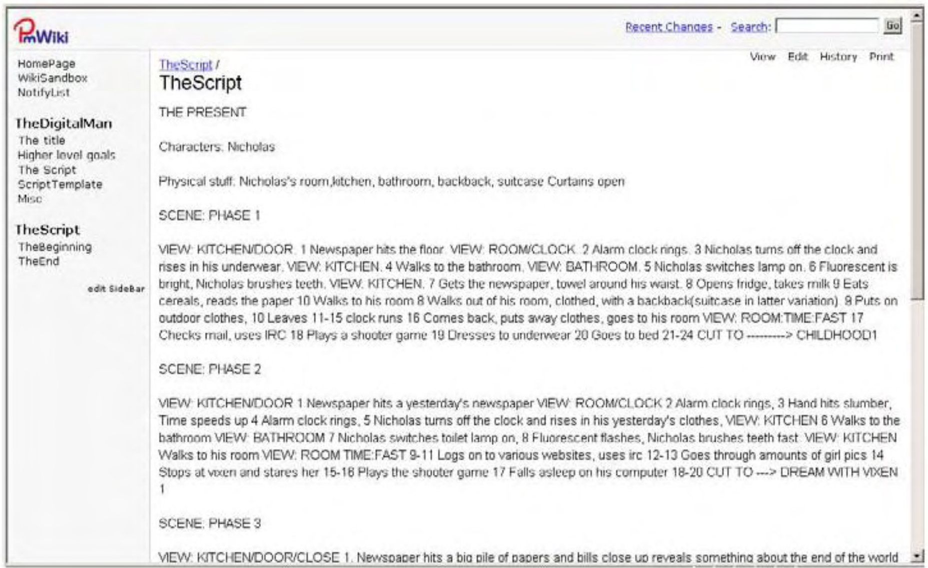


Fig. 3. Screenshot of the PmWiki system prepared for collaborative script-writing.

be based on, as well as a central message to get across to the audience. The presentations contained quick drafts of some key scenes as imagined by the group. After all groups had presented their ideas, the class voted anonymously for their favorite, which was to become the basis for the final script.

From this point on, the idea was to collaboratively refine the basic story by contributing ideas, scenes, dialogs, and other details via Wiki tools. The online Wiki-system PmWiki [PmWiki, http://www.pmwiki.org/] was selected and served as the central platform for collecting all contributions. The group whose script had been democratically selected as the winning story put their superficial version of the script onto the Wiki. Other sections of the Wiki system were used for collecting ideas, title suggestions, and character descriptions.

Originally, the script was divided into chapters, each presented by a separate thread in the Wiki, but the students mostly merged their input directly with the overall preliminary version. Even though the Wiki contained a change tracker and allowed the user to view the history of the thread, the script soon became messy. This was due to the fact, that students had different writing styles, formats, and a lack of moderation with Wiki tools, owing to the category of tools. At the end of the online collaboration, a single train of thought was no longer obvious; a coherent story-line was lost. It was necessary to refine and finalize the script in a face-to-face meeting among a small group of volunteers. This lead to a more compact script, based on the original idea. This version incorporated many of the students' contributions as well. Furthermore, the script was stripped down to the point where it was realizable in the available amount of time. In addition, a storyboard was drafted which illustrated the scenes as imagined by the small group of volunteer scriptwriters.

4.3 Experiences in Collaborative Script-Writing and Wiki

A poll among students that provided information about their experience in collaborative scriptwriting using Wiki tools was done retrospectively via a questionnaire. The goal was

Table II. Demographic Description of Students in this Course.

Demographic description	
Gender	80% Male, 20% Female
Age	M=24,5; SD= 3,5 years
Previous film-making experience	No 73%, Yes 27%
Nationalities:	Finnish, German, Polish, Spanish, Italian
Technical background:	100%

to evaluate comfortable and uncomfortable factors and major improvements in the scriptwriting process as a part of the course in order to improve it in the future. The questionnaire included both closed and open questions. Eight closed questions presented claims to be answered in a seven-point scale (strongly agree to strongly disagree); six open questions were also presented. Data collection was targeted for all the students who participated on the course. The questionnaire was posted via the online tool Webropol at the end of the course [http://www.wikipedia.org].

The answer rate was 80%. Most of the participants were male, novices in film-making, represented several nationalities, and had technical background (see Table **). Descriptive results including mean and standard deviations for each claim are shown in**

Table. Low mean values can be interpreted as strong agreement and high mean values as strong disagreement. The results of closed questions do not present strong arguments as to whether collaborative scriptwriting was a motivating part of the course, or whether it should it be part of a course in the future. However, people did feel that their ideas were taken into account during the process. The descriptions of using Wiki tools in scriptwriting agreed that the tool was not suitable for collaborative scriptwriting; it was found uncomfortable and unpleasant to use.

Analysis of open questions used a data-driven approach, called Grounded theory. It can be used when the research area is relatively unexplored and the research aims at understanding the meaning or nature of a person's experiences [Strauss and Corbin 1998].

The results from the experience in the collaborative scriptwriting process summarize its comfortable and uncomfortable factors. It should act as a guide in finding the biggest

Table III. Descriptive Results with Mean and Standard Derivations for Each Claim

Claim	**Mean**	**Standard Deviation**
Collaborative script-writing was a motivating part of the course	4.0	2.3
Script-writing should be included in the course in the future as well	3.9	2.3
I was motivated to contribute to script-writing, but I felt that my ideas were not taken into account	5.1	2.1
I felt that collaborative script-writing online with Wiki tools was successful	5.2	2.7
The Wiki system supported collaborative script-writing tasks	4.2	1.9
The Wiki system was easy to use	3.5	1.9
The Wiki system was not easy to learn to use	6.4	2.0

The Wiki system was pleasant to use	4.5	2.1

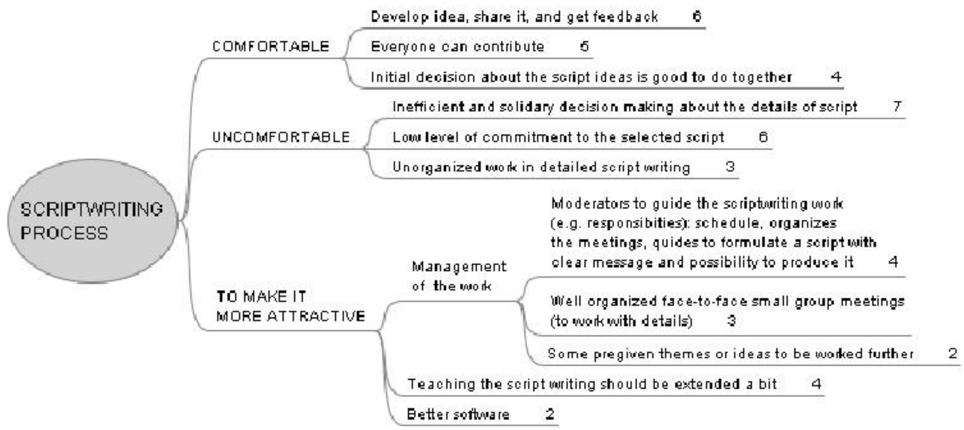


Fig. 4. Student experience in the collaborative script-writing process. The numbers in each branch show the number of cmentions in each category.

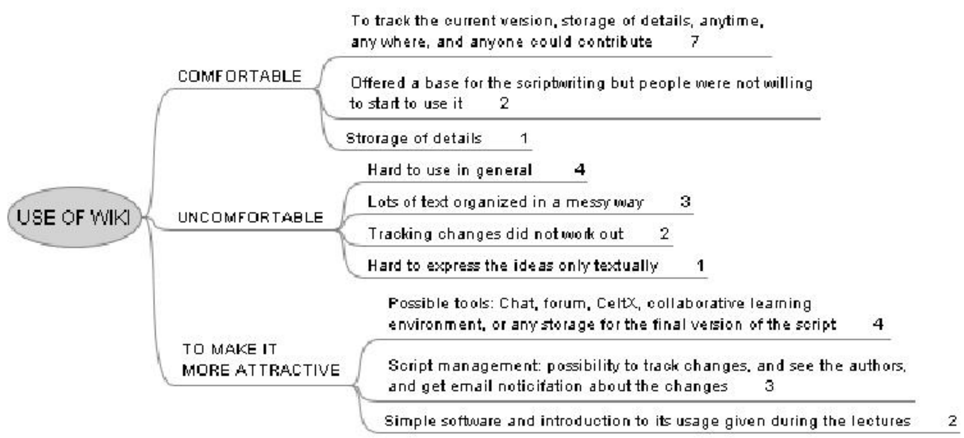


Fig. 5. Student experience using Wiki tools as part of collaborative script-writing process. The numbers in each branch show the number of mentions in each category.

challenges for similar teaching projects in the future (see
Fig. 4). Brainstorming and the possibility for everyone to contribute at the every early and general stage of scriptwriting was described as pleasant part of the process. However, the detailed scriptwriting process
was found uncomfortable due to inefficient decision-making on details, a low level of commitment to the script, and a generally unorganized working style. To get beyond these negative factors, suggestions to future collaborative attempts were the following: organize a bit more teaching on the topic; start the process with a pre-defined theme or ideas; or work so that the process is partly guided by a moderator organizing good face-to-face meetings, especially during detailed scriptwriting; and finally use better software.

Use of the Wiki tool as a part of collaborative scriptwriting process was examined for comfortable and uncomfortable factors, which should suggest improvements for the future to make its use more attractive (see Fig. 5).

4.4 Applying Online Collaborative Tools to Film-Making

Using the Wiki tool was experienced as pleasant because it offered to store the script so it could be viewed anytime, anyplace, and by anyone. It was also seen as a good platform. However, people were reluctant to start using it: it had a huge amount of weakly organized text, expression was limited to text, and it lacked a feature to track changes, which all made the Wiki tool uncomfortable to use. Software should be simple, and a short introduction should be given at the beginning of the process to make people more willing to use it. If any software is to be used to support collaborative scriptwriting, it should have more features for script management, including online synchronous and asynchronous working possibilities and storage for the final version. There should also be a feature for tracking changes, see the changes others have made, and send email notification whenever changes are made.

Another option for applying collaborative script-writing technology is the well-known software tool, celtx [http://www.celtx.com/]. Celtx is increasingly evolving to a quasi-standard software in terms of screenwriting. Besides providing collaboration features and scheduling tasks among multiple authors, it offers the creation of storyboard sequences and the possibility of tagging certain elements in the pre-production phase. It runs on several operating systems and is free and open-source.

5. DIGITAL HD PRODUCTION WORFLOW BASED ON MXF METADATA

As stated in the previous section, collaborative cooperation with Wiki Tools is a useful, and nowadays widely appreciated, method for shared collaborative content pre-production. However, the more participants are involved in the co-preparation of the media material, the greater the number of contributions that have to be taken into consideration while deciding on the final version. This affects the production workflow as well. To allow for a full digital production workflow, new digital tools for enabling a (semi-) automated flow are necessary. The idea is to make all data associated with the essence (the actual material) available at each workflow step. This relates to information about the script, the script itself, why specific decisions have been made, camera settings, shooting quality, camera reports, and shot descriptions. This section describes the step that enables a digital workflow between pre-production, production, and post-production. Since comparing the different points of view of the movie-maker team and decisions during the production phase are pivotal aspects of collaborative cooperation, especially

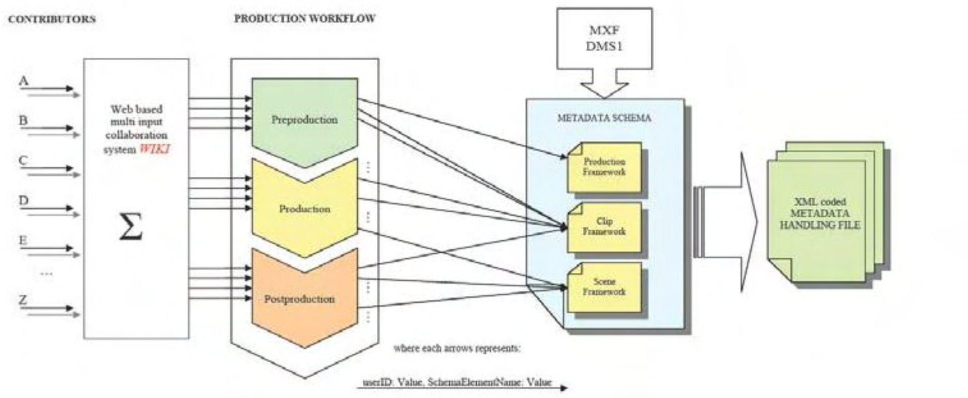


Fig.6. Applying the Material eXchange Format (MXF) as a digital workflow management tool within the scope of E=MC2+1.

while using new information exchange systems, all information, including single parameters, must be stored, correctly assigned to existing material, preserved, and what is more, uniquely identified.

The technology to cope with the digital production workflow in E=MC2+1 is the Material eXchange Format (MXF) [http://www.mxf.org/] in combination with a web-based information management system developed by the research group [Golebiowski 2006; 2007]. An overview of how MXF was applied for E=MC2+1 can be seen in

Fig.6. The MXF information management system had the following tasks:

- digital management of the movie-script;
- storage of captured data (e.g., camera parameter); and
- generation and annotation of shot descriptions, storyboard, special effect sheets, and camera reports.

5.1 Material eXchange Format (MXF) Basics

Metadata fully describes essence, and is a cornerstone in content preparation. Metadata itself must be logically arranged, extendible, and easily accessible. Besides numerous database solutions for metadata storage and supervision, the XML coded metadata schemas [Caplan 2003/2004] represent one of the most important possibilities for metadata administration. Correct and effortlessly available metadata schemas ensure preservation and powerful digital content management in preparing the workflow, as well as at the very end of the production chain (i.e., distribution and play-out). MXF provides a solution especially suited for the movie production side.

MXF is a wrapper format, which can encapsulate essence and all associated data with it. MXF is (mostly) standardized by SMPTE [http://www.smpte.org] and is used as professional production format for enabling a fully digital workflow. We applied the MXF information system, which was developed by the NAMU research group at the Tampere University of Technology. In principle, the MXF standard consists of two major elements (standards available from SMPTE):

- the wrapper element allows encapsulating any type of content into a package (e.g., audio-visual content); and

- the DMS1 specification allows tagging production information to essence (e.g., shot description).

The application of MXF DMS1 metadata, besides delivering the production information, storage medium, and a management system, also delivers the complete description of the material and essence-related matters. The MXF description may also serve as the source of information for public essence description in the form of a narrative summary, subject description, or genre for programs' web portals or TV guides.

MXF DMS1 elements consist of many different production-associated parameters and characteristics arranged into frameworks via metadata. Each framework encapsulates a set of logically interconnected elements essential during the production process. Thus, the production framework stores all administrative information such as staff data, contributors, and so on. The clip framework organizes the pre-production and capture process and collects related data related. Thus it organizes information in pre-production, covers the capture process, and is capable of assigning shot descriptions, shot animations, camera parameters, and set in/out points to essence. The scene framework of MXF wraps scene-elated information, such as placing actors in a timeline.

Moreover, the MXF elements identification method ensures the unique identification of single essence elements. Due to the possibility of storing different versions of the same material, it is not sufficient to use scene, shot, and sub-shot numbers. MXF provides unique identification of essence elements via UUIDs, which are a unique generated hexadecimal value. However, every database entry must be localizable via a unique identifier according the MXF DMS1 specification. To comply with real movie production, the identification of each shot is also identified with a triple scene number/shot number/sub-shot number.

5.2 Applying MXF to the E=MC2+1 Production Case

In E=MC2+1, the collaborative script-writing was done with the help of Wiki tools. The final script was inserted in our MXF-based information management system for further processing. During the production process, we experimented with modern digital production technology to emphasize collaborative processes as well. We stored the movie script in the MXF information system. After the storyboard, including its graphics, had been generated, this was stored in the same system as well (see **Fig. 7**).

During production, collaborative access to the data was possible, but a decision on production-related issues was left to professionals rather than to a democratic decision to maintain the highest quality. In practice, decisions on camera settings, action flow, shot quality classification, and additional information on the participants' individual preferences were stored in the MXF information system. In the case of E=MC2+1, the MXF information system was not used as a collaborative tool, but as a tool for professionals to manage relevant data during capture. A collaborative approach in using these tools would have been counter-productive at this step.

CAMERA ANGLES - STORYBOARD - FOR: E=MC2

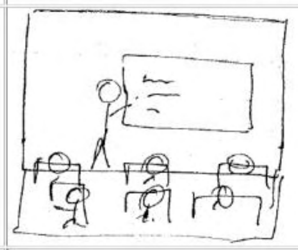
SCENE NO	SHOT NO	SHOT TYPE	DESCRIPTION	SHOT DESIGN
1	1	Wide	General view of the classroom -> from the back. Teacher starts the lecture. Some equations and figures already on the blackboard.	
1	2	CU	View: classroom/person 1 - close. Person 1 sweats and holds his head with both hands. Painful expression on his face, 8kHz wave is heard on top of everything.	

Fig. 7. Storyboard generated on the basis of MXF metadata.

E=MC2 version 1

SHOT ID	1/3/1	***TAPE NO***	1
TIMECODE	***START:***	01.20.35.22	
	STOP:	01.21.35.22	
PLACE	The location of an action. Nijinsky's room.	***TIME***	Night
ACTORS	All crew. Student 2, Student 3(GIRL), Student 6.		
ACTION DESCRIPTION	Student 2 is making moveon Girl (Student 3), but is too wasted. He gets nauseated and needs go to the bathroom. Some less drunk guy (Student 6) comes in and start to chat with the girl.		
REQUISITS	Glasses full of beer and drinks, Normal disco equipment. huge speakers next to the dance floor.		
CAMERA MOVEMENT	Translation to higher elevations (Y) in meters : -0.18		
OBJECTIVE	10	***FOCAL INFO***	6
CAMERA HEIGHT	0.25		
DISTANCE TO OBJECT	1.76		
LIGHT	Disco red - yellow lights.		
BLUE SCREEN	No effects		
3D	No effects		
COMMENTS	Girl chatting with girlfriend, sitting by the table in the left corner of the room. Other students in the background.		

Fig. 8. Shot report for one shot based on MXF metadata.

While the MXF information system was used to manage data coming from pre-production phases before capture, during production it had two tasks. The first was to manage production metadata coming from the camera; the second was to generate reports after shooting. These reports included the camera report (see **Fig. 9**) as well as the special effect sheets (see **Fig. 8**). The camera report shows essential information related to time-codes and brief shot descriptions. The special effect sheets represent all information related to special effects and their setup.

namu	CAMREA REPORT	Production Setting Date:	21.02.2007	Page:	1/3
Production / CO.:	E=MC2+1/2007	Main Title:	E=MC2+1		
Director:	Mr Piotr Golebiowski	Cameraman:	Mr Adrian Hornsby	Recordist:	Mr Jarkko Kauranen
Camera:	Sony HD	Film:		Storage Medium No.:	1

Scene No.	Picture No.	Take No.	Start Time	Stop Time	Essential Info.	Lens Info.	Camera Height
1	1	1	01.00.40.01	01.01.41.13	Shadow of the camera. Camera on teh opposite side of the classroom.	10	1.23
		2	01.01.41.13	01.02.27.01	Lights ok. Slight movement in the entrence door direction necessary.		
		3	01.02.27.01	01.03.23.16	OK		
4	13	1	01.03.23.16	01.04.20.23	Students leave class room too fast.	10	1.23
		2	01.04.20.23	01.05.28.02	Teacher - wrong hand on the desk.		
		3	01.05.28.02	01.06.05.10	OK		
		4	01.06.05.10	01.06.44.10	Too slow action.		

Fig. 9. Web-based daily camera report based on MXF metadata.

5.3 MXF for Screenplay, Storyboard, Special Effect Sheets, and Camera Reports

The MXF DMS1 standards contain a wide variety of film and broadcast industry parameters. These parameters can be used to generate other production-related documentation in the form of special effect sheets, shot lists, and camera reports during production.

The specific parameters required to fill these reports are defined by the SMPTE RP210.6 Dictionary, which defines the structure of data during capture, as for example objective information, focal information, camera height, or camera object distance required for capture. The production framework defines the structure of production-global valid data and was mostly used for generating the camera reports. This data included production dates, director, cameraman, title sets, timeline information, and was the basis for generating camera reports.

Taking the E=MC2+1 collaborative script-writing as an example, all script versions are stored in the centralized Wiki repository and can be accessed by any registered collaborator. Using the MXF information system, automatic script generation is possible by a simple single click. Each Wiki entry of the movie-script needs to be added to the MXF-based information system. For example, shot comments (*ShotComment*) originating from Wiki are added to the author of the comment (*ShotCommentKind*). Thus, at this stage, the MXF-based information system contains more possible versions for the movie-script.

However, the decision on the final script version must be taken beforehand, since the actual script must consist of a unique sequence of single scenes, including several shots. In other words, if several different versions of single shots are stored in the repository, many different versions of shots will lead to many different versions of the total script. Should the final script contain numerous entries with the same shot identification, errors are reported by the system, as the final version entries have to be uniquely identified. Optional sequences can be annotated via a Boolean flag (*IsOptional*) to indicate the script optional or required elements. XSLT transformations in combination with XQueries are used to generate a human-readable form of the final movie script. The final version only includes the non-optional elements of the database entries.

The storyboard is edited on the basis of the movie script, and is manually annotated. Additional storyboard images can be uploaded to the MXF information system. The storyboard contains sufficient information to initialize the capture of the movie.

However, the real essence of collaboration in movie-making - despite the high importance of extra information - is the movie as such. So the "real" essence is captured in the next step of production. All information required for camera reports and special effect sheets has been collected and added to the MXF information system. The generation of reports is based on XQueries and XSLT style-sheets as well, to make them readable to humans. This follows the two-way input approach of metadata and essence as discussed in Cox et al. [2006]. More practical examples of MXF files can be found in Appendix A, in **Fig. 12**, and in **Table** .

6. DIGITAL HD POST-PRODUCTION

After the capture process, the next step is post-production. In post-production the final movie is created by arranging suitable parts of the footage in a correct and timely order. From the director's artistic viewpoint, the original material is simply a huge number of different shots. During the post-production process, especially during editing, special effects and sound are added, and faults in the material corrected.

Traditionally, editing required the physical cutting of the original material, and afterwards gluing it together. Nowadays the process is called non-linear editing. Traditional editing was tricky, as the original material was processed, but it let the editor or director of the movie have more of a relationship to his material. With the emergence of videotape-based editing, a new linear editing method was becoming available. The desired parts of a movie were copied from the original tape to a master-tape. The copying process led to quality degradation, and analogue devices were mostly used in the process. Special effects could also only be added with difficulty, as they had to be created in real-time while the material was being copied. Due to the tape-like workflow, this method was called linear editing.

However, modern editing systems are usually fully digital. The original analogue film is digitized and processed by a computer system. In principle, this is a step backward to the non-linear editing method. Computer-based editing has the advantage that a film can be edited virtually rather than on the actual material. A virtual timeline in the computer system acts as container for the actual material. This can also be described as file-based editing, as the original material is pulled from digital tapes and converted to clips stored on a hard disk. It is obvious that the storage space becomes a major issue and high computational power is required to realize the image and sound processing tasks. E=MC2+1 was edited using this method.

For E=MC2+1, the material was captured on digital tape and afterwards copied to the computer's hard disk. Where the essence was available on hard disk, the MXF information system was used to manage all the essence-associated data. As our editing station did not support MXF as a wrapper standard, this seemed to be the most efficient way of working with the material. For editing, Adobe Premiere was facilitated. Unfortunately, various scenes could not be detected during the capture of the HD material from tape, as Adobe Premiere did not support this functionality. This made it difficult to edit the high-resolution material, which led to huge files on the hard disk that were cut manually using editing software.

Another problem was that the audio sync was frequently lost in the middle of the clips, and this could only be corrected manually. Despite this, the basic editing was quite smooth, and no more problems appeared. But we were faced with new challenges when we added color-correction filters and other effects, and the computer system had to deal with a rather demanding and difficult task. Despite an InterCore 2 Dual processor and 3 GB of memory, the process still seemed very slow, and we ran out of memory many times. We could not track back if this problem was due to too little computational power or to the editing software.

The Adobe After Effects software was used to create the special effects. However, for E=MC2+1, we wanted only a few simple effects, as the student team did not have the professional experience required for more complex special effects. The effects we were aiming at were

- green-screen compositing with chroma keying;
- slow motion effects; and
- color correction.

As in previous versions of Adobe products, After Effects and Premiere integrated well. After adding the special effects, we obtained a final master of the movie, which was a huge uncompressed HD file. The final master was used to encode different versions for distribution to IP-TV, DVD, or mobile-TV.

6.1 Green-Screen Compositing with Chroma Keying

Fig. 10. E=MC2+1 chroma keying shot of actors and beach background.

Chroma-keying allows us to segment objects from the background and to combine them with another background. In practice, a color transparency is created and replaced by another image. This technique is currently extensively used for weather forecasts, elections, and some children's TV shows. The foreground object (e.g., the presenter of today's weather) is in front of a solid colored background. The solid colored background is replaced by another background - n the case of today's weather, with the weather map. Typically, this is a non-human-flesh color such as blue, but a green background can also be used for this purpose.

Traditionally, analogue video mixers in combination with a blue background were used, since blue is one of the three main colors that is not or very rarely part of the color of human flesh. Green backgrounds have become popular, as they give better results when working with compressed digital video formats. It is also a much brighter color than blue, as its luminance value is higher. A green background makes for better results and needs less light in lightening a scene. It provides another advantage, as today's single-chip cameras perform better with a green background due to the structure of the chip.

In E=MC2+1, one compositing shot was created by using the chroma key effect. Compositing is the process of adding up the various layers of image material. In the scene in which a student in a classroom is dreaming about a holiday with his girlfriend, the dream image was taken against a green background. The final effect was then created in Adobe After Effects, which had the tools required for keying; specifically, the keylight effect. (We had to fine-tune the settings to make decent results with not-so-perfect video material.) As the course was intended for non-film-makers, it was obvious that the original material would not be perfect. To obtain good results, required a greater amount of work in post-production. The major problem was lightening the background, which was not properly arranged for during shooting, so that some areas at the bottom of the image were darker than others. Another problem was the lady's sun-glasses: it was rather difficult to make the sunglasses look good and make all the green areas transparent at the same time. The problem was solved by using various keying settings for different parts of the image.

6.2 Slow Motion Effect

E=mc2+1 has several scenes with alternations in speed. One scene is completely implemented at a high speed: a scene in which a nerd goes to ask for a cigarette from the "cool student" in a bar. The original action material in the scene had only two image sizes. One was very large, so it was not usable most of the time. The action in the shot took quite a long time, so showing it in real time would have broken the rhythm of the movie. Hence the solution was to speed up the action and show only the important parts. The other parts were cut when there was no possibility of changing the image size. The result was still nice, because the audio consisted of music only (as in music videos).

Slow motion was used in some other scenes. The green screen scene, where one student is dreaming of a holiday with his girlfriend, included playback at half speed to give a more "dreamy" feeling to the scene. The effect was made by actually doubling the number of frames. Every other frame was created using information from the next and previous frame. Motion vectors were used for creating the new frames. So it was an implementation of morphing. The result was quite natural, as though it had been filmed at a double frame rate and then played back at a normal frame rate (although the disadvantage is that this method needs quite heavy calculation: together with the green screen effect, After Effects took almost three hours to render this seven-second effect). Also, it often fails with complicated backgrounds or items like rotating objects that change shapes fast. This effect was also used in a scene where a girl student turns her head towards another student who flirts with her, although her boyfriend is sitting with her. The slow turn of the head made the scene more dramatic.

Another type of slow motion was used in the last of the party scenes in which the teacher falls down at the party and the image cuts to the classroom where he falls asleep. The slow effect is basically slow motion, but frame blending gives more motion blur to the image and makes the movement smoother.

6.3 Color Correction

Color correction is a process that includes selecting correct lighting and camera settings when shooting the scene. As this is frequently faulty, tuning the colors in post-production is required. The scene can often be made more interesting by adding light sources with different colored lights. The final goal is not always to create a realistic image as possible, but to create images that best serve their purposes. Two examples are the creation of a beautiful visual and the evocation of a mood. Typically this means modifications to all aspects of the image, not just setting the color temperatures. The contrast can be altered in many ways, leading to rather complex processes.

For E=mc2+1, the editing application (Adobe Premiere) was also used for color correction. In practice, the corrections were done by using a combination of various effects settings. The basic tools were contrast curves designed for each scene, for luminance, and red, green, and blue channels.

Another issue was that our movie took place at two completely different locations: the lecture and the party.

The lecture scenes were supposed to happen in the morning, when students are tired due to partying the night before. So the lecture scenes were set to look colder compared to the party images. This represented the mood of the students visually in a better way. During capture, the original material was recorded using the basic camera settings, however the settings were set to film-like gamma to create a movie look. To create a darker mood for the students, some compression was done to the black tones in the image. Brighter tones were not altered. In wider images, the effect was applied in a milder way. A colder color was achieved by changing tones, especially in the mid-range, a little bit towards blue and by reducing saturation while keeping the whites white.

The party scene presented a completely different kind of situation for color correction. The color here should be different from the other scenes, which were shot with different camera settings as well. So another type of cinematic gamma was used, and the blacks were compressed somewhat. The lighting in the scene included a purple fluorescent light, a greenish fluorescent light, and some indirect light from regular 3200K halogens. In the dancing scenes, the purple light was dominant. The purple tones were changed towards red in the color correction, and the effect of the greenish light was emphasized. As result, the colors in the dancing scenes were dominated by a combination of red and green. In the other parts of the room the purple light was not dominant, so different color correction settings had to be applied. The room was actually quite dark for movie production purposes, and so grain was used in the camera, which is not usually a good thing in feature film production, but in this case it was considered a practical solution. The dim lighting with different colors served our purpose better than a bright studio-like environment. At the beginning there was 6db more grain in the image than in classroom scenes. Still, the visible film-like grain seen in the image in the party scenes is mostly generated in post-production. The contrast in the scene was enhanced by lifting some areas in tonal range while suppressing black more. In a couple of clips a smoke effect machine was tested at the location, but it only caused the blacks to rise towards grey. This was corrected in post-production.

6.4 Audio Editing

Audio is an important part of a movie, and may also need a lot of work in many editing projects. In the case of E=MC2+1, audio was recorded on location using a hard disk recorder. The audio clips were synchronized to the video later using the editing software.

The music for the movie, a song called "Quantization Matrix" was written and composed by a student in the course; the clips were also added during the editing process.

The voice tracks were compressed to make the speech clearer. EQ was used to make the speech sound correct, and to fit the music and speech to the scenes. The audio levels were corrected, and the music was mixed a (a bit) lower than speech.

7. HD DISTRIBUTION OF THE MOVIE

Since the goal of the course was to look at the complete production chain, from scene to screen, we tested the following distribution methods for HD content:

- IP-TV
- DVB-T
- DVB-H
- DVD

7.1 Distribution for Television

The laboratories at the Tampere University of Technology (TUT) were utilized for distribution (system architecture in **Fig. 11**). The laboratories provide the technical facilities and environments for both the full-chain DVB test-bed [European Telecommunications Standards Institute (ETSI) 2004] and the IP multicast network. Hence the selected platforms were based on DVB and IP-TV. Today these technologies represent the most common distribution media. In addition, TUT provides a mobile streaming test-bed. To test this distribution channel, the material was transcoded for DVB and resolution and bitrates downscaled for mobile broadcasts. Several digital television distribution channels (DVB-T, IP-TV, and DVB-H) were utilized to find ideal requirements for HD content.

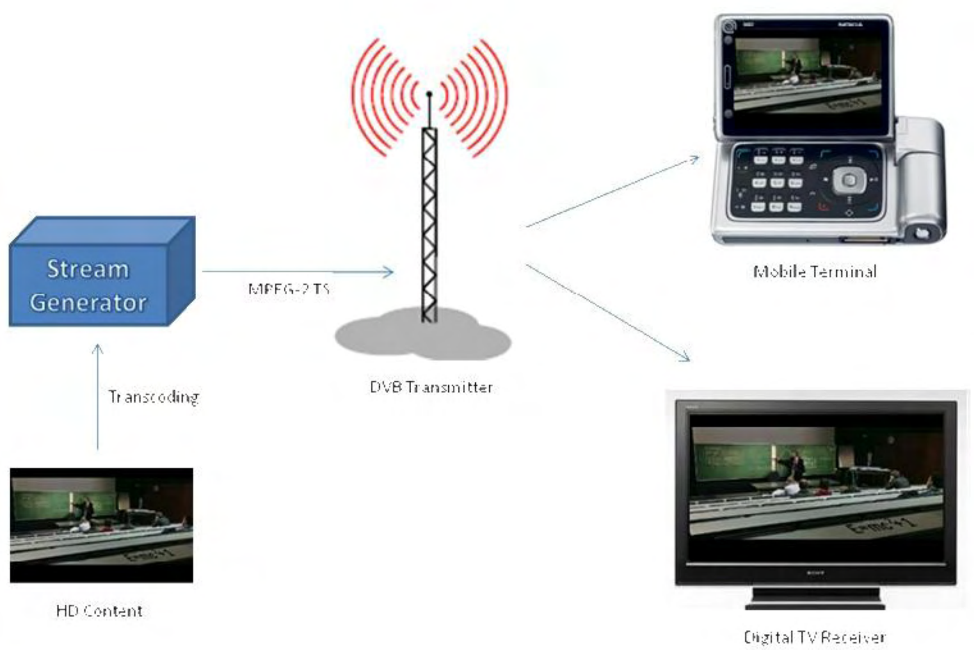


Fig. 11. DVB distribution architecture.

The main components of the DVB test-bed are the stream generator and the transmitter. In addition, content servers and content description tools are used when needed. Eventually this could facilitate the creation of an Electronic Service Guide (ESG) [European Telecommunications Standards Institute (ETSI) 2006] for mobile broadcast. We used a wide range of available set-top-boxes, PC cards, mobile phones, and USB sticks as reception devices for DVB applications for terrestrial and mobile reception. For DVB-H [European Telecommunications Standards Institute (ETSI) 2004], we tested our system with the Nokia N92 acting as a mobile television receiver.

The heart of the system is the stream generator, which is a server for creating an MPEG-2 Transport Stream and feeding it to the transmitter through an ASI interface. The TS can also be created separately and saved on the server for the transmission. In addition to generating the MPEG-2 TS, the server provides all the necessary properties to manage DVB-T/H broadcasting. It creates the PSI/SI tables [European Telecommunications Standards Institute (ETSI) 2005] and executes IP encapsulation for the DVB-H network and other mobile broadcast-related properties like Multi-Protocol Encapsulation (MPE), time-slicing, and MPE-FEC (Forward Error Correction).

The transmitter system is professional equipment for DVB provided by Rohde and Schwarz. It contains an exciter unit, two 50W amplifiers, a separate unit for controlling the amplifiers, two vertically polarized omni-directional antennas, and two bi-directional antennas. The dual-amplifier multi-antenna system is built for testing diverse transmissions. The exciter unit includes encoder, pre-corrector, modulator, and synthesizer for signal generation. It is equipped with operating and monitoring software installed on a PC which is connected to the exciter through a serial interface. The software provides full control of the exciter properties and transmission parameter modifications. The amplifier control unit is manufactured separately to flawlessly adjust output power. The antennas are installed on the roof at 25 meters above ground level. The other antenna combination is located on a moving platform to adjust the distance between antennas.

7.1.1 *Transcoding the Material.* The content had to be transcoded into a compliant format in order to be distributed through a DVB network. For DVB-H distribution, the material was encoded into MPEG-4 format, optionally using H.264 coding. All mobile terminals equipped with a mobile television (DVB-H) receiver support these formats. The bit-rate of the encoded streams was reduced to 500 kbps and the resolution was down-scaled to 320x180. The bit-rate of 3000 kbps and the resolution of 720x576 were also used experimentally.

For DVB-T distribution, the material was directly transcoded into MPEG-2 TS format. Some professional TS editing was also needed to add the network information required by DVB-T receivers. The parameters of the transcoded streams are described in. All these streams were also used in IP-TV experiments.

Table IV. Transcoded Streams

Version	File Format	Codec	Bitrate / kbps	Resolution	Target platform
1	mp4	MPEG-4	500	320x180	DVB-H
2	mp4	H.264	500	320x180	DVB-H
3	mp4	MPEG-4	3000	720x576	DVB-H
4	mp4	H.264	3000	720x576	DVB-H
5	trp	MPEG-2 TS	6000	720x576	DVB-T

7.1.2 *Results of the Experiments.* To test the mobile television-viewing experience, a Nokia N92 multimedia phone was used. At the moment it is one of the few phones equipped with a mobile TV (DVB-H) receiver. To test the reception quality, the transcoded streams were transmitted using the DVB system and received with the phone. The viewer experience and reception quality were good with 500 kbps streams, but 3000 kbps streams were already too heavy for the receiver, causing a deterioration in video quality. These results suggest that even lower bitrates (200 to 300 kbps) could be used in the mobile television environment and still achieve good quality.

The digital television was tested with a digital DVB-T receiver (STB) and a plasma screen. The reception and video quality were excellent, as the bit-rate (6000 kbps) was higher than usual (2000 to 4000 kbps) in a digital television environment. IPTV experiments were performed with all the streams using the VLC application to feed them to a multicast network. The results were good in every case, but it was noticeable that in an IPTV environment, network load and network performance capabilities played a big role in reception quality. In conclusion, all the experiments were done using down-scaled resolution, even when DVB-T and IPTV allowed full HD resolution. This will be the goal in future testing.

7.2 DVD Production

To prevent any copyright problems with commercial entities, a condition for the DVD menu was to draw on self-produced materials only. This restriction not only offered a financial advantage but it also furthered an original design of the menu. The main purpose of the menu design was to give a foretaste of the movie with interesting pictures to tease the audience. The final implementation consisted of two parts: the background picture with a second layer that overlapped the proper image borders and a collage of the actors in the form of an animated movie strip that makes the menu more active. All these images were extracted from the movie which has a widescreen HD resolution.

As the images were calculated with squared pixels, the exported pictures had to be horizontally resized for a correct resolution. A further objective was to emphasize the funny character of the movie. This comic style was realized via two rapidly sliding menu objects and by an open source font type to create chalk-like menu text in front of the blackboard. In addition, music was composed to support both the activity and the humor of the menu. This music was based on the piano harmonies of the song in the movie, called "Quantization Matrix". The software we used was the Adobe Production Suite. The menu was designed in Photoshop, image extraction was done with Premiere Pro 2.0, the animated menu was created with After Effects 7.0, and the final DVD was built by Encore DVD 2.0. As of today, not every DVD player supports HD movies, so this DVD contains a standard version. Additionally it holds an HD version for the computer in a separate folder, and the still images shown in the DVD gallery are stored as JPEG in a DVD folder as well.

8. DISCUSSION

Tampere University of Technology (TUT) in general and the NAMU (New AMbient MUltimedia Research) group in particular offer courses based on the latest available technologies. Students not only have the opportunity to learn, but to also experience contact with cutting-edge technology.

The NAMU group offers courses in which students have the opportunity to experiment with the latest developments in technology to realize their own ideas. The concept of learn-by-doing is implemented in the content production course mentioned in this article. Although the implementation of more experimental tasks requires additional work from the faculty, as the teaching effort increases with the practical exercises, the advantages to the students makes it worth the additional effort.

The experience of learning-by-doing improved innovation and collaboration among the participants of the course. The students were eager to obtain solutions the moment their tasks were complete. The open environment allowed the students to use their imaginations, and provide solutions that overcame their difficulties.

The implementation of a Wiki environment came after some of the course participants had difficulty in arranging meetings for editing the script. Open-source software solutions such as Wiki software encouraged the team to install new software quickly.

The students' involvement in course activity demonstrated their interest in collaboration and learning. The fact of collaboration is remarkable, far from the typical course where the main objective is passing the exam.

The video production process was an educational one, where knowledge related to media technologies was created and developed. Its main outcome was a short movie, the result of inputs from all class-team members. In general, teamwork is superior to an individual working alone. The greater human resources sharpen ideas through discussion and argument, and support for a tentative idea motivates a common successful outcome. But teamwork might end up with disappointing results due simply to a lack of communication or contradictory opinions. During our course, the process was controlled by avoiding unnecessary team meetings; although generalized comments were emailed to all the members, providing observations and information with suggestions on how to continue.

We also recognized that special tasks could be done more effectively by individuals rather than teamwork. The video production process involved many stages, so that tasks and areas of responsibility were shared by class participants. The responsibilities varied: there was a director and assistant director; cinematographer; camera, sound, and light crew; music, sound, and graphics designers; a production designer and a stylist; SFX supervisor; production manager; editor; workflow manager; and a group of student actors. As the tasks were shared, knowledge became diffused through the group; no one person had a monopoly of knowledge. This approach was different from that in a traditional class and required students to become self-regulated and collaborative learners.

Collaboration is a process defined by the interaction of knowledge and mutual learning among two or more people working together towards a common goal, typically creative in nature [Wikipedia. http://www.wikipedia.org]. Collaborative learning requires participation in a learning community, but it limits individual flexibility [http://home.nettskolen.com/~morten/], hence its success may depend on a mutual understanding that all participants have an obligation or commitment to it. Collaboration was successful in this course, but typical group dynamics, especially during script-writing, were visible. Many different opinions, personal viewpoints, and approaches led to strong and heavy discussions. As pure technology-oriented courses tend to present theorems, a more creative course tends to involve human emotions.

Nowadays, as media technologies are evolving, collaboration in knowledge creation can be easily realized. There are various learning environments, management systems, shared boards, forums, chats, and so on, where students can express their ideas, learn from each other, find answers to their problems disregarding time and place constrains. Special opportunities can be created by free and open source software (F/OSS). One of the significant features of F/ OSS is that they can be accessed, formatted, enhanced, and applied by any internet user; the Wiki open-source tool was used in this course.

This course was different from a traditional one: the overall goal and problems were set by the course instructor, but the students could set their own learning objectives. The areas of their responsibility were divided according to their preferences (e.g., interest in the camera). Formal instruction was avoided, but still (or perhaps due to this factor) students were motivated to participate in this course.

ACKNOWLEDGMENTS

The credit for this article belongs to the production team and the enthusiastic students involved in the production. The practical work and experiments were performed by the students: Section 3 was mostly contributed by Adrian Hornsby; Section 4, by Satu Jumisko-Pyykko, Volker Bruns, and Simon Reymann; Section 5, by Piotr Golebiowski;

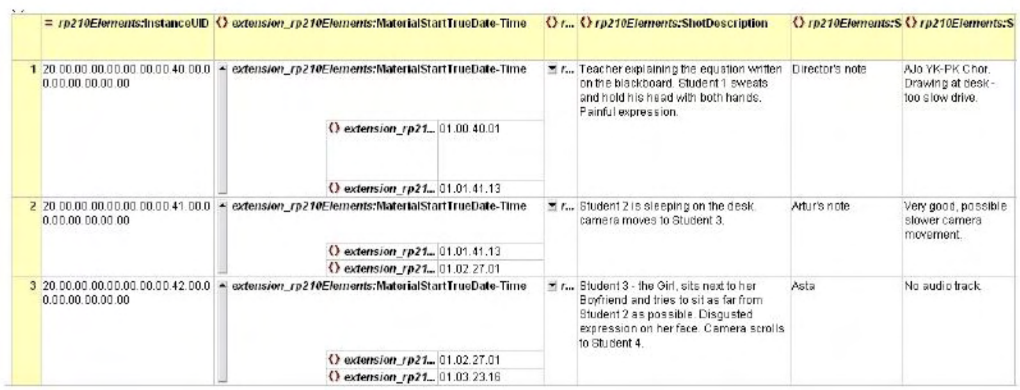
Section 6, by Jarkko Kaurnen; Section 7, by Mikko Oksanen and Dirk Matthes; and Section 8, by Asta Kybartaite and Fernando Ubis.

APPENDIX A: DETAILED MXF EXAMPLES

Table V. Example MXF File that Describes One Shot (take)

```
…
<rp210Elements:TakeNumber>10</rp210Elements:TakeNumber>
<extension_rp210Elements:IsOptional>false</extension_rp210Elements:IsOptional>
<rp210Elements:ScriptingSets>
   <DMS1:Scriptingrp210Elements:InstanceUID="23.00.00.00.00.00.00.00.30.00.00.
                                            00.00.00.00.00">
      <rp210Elements:ScriptingKind>Script</rp210Elements:ScriptingKind>
      <rp210Elements:ScriptingText>Student 1 sits with head down.
         </rp210Elements:ScriptingText>
   </DMS1:Scripting>
</rp210Elements:ScriptingSets>
<rp210Elements:TakeNumber>10</rp210Elements:TakeNumber>
<extension_rp210Elements:IsOptional>true</extension_rp210Elements:IsOptional>

<rp210Elements:ScriptingSets>
      <DMS1:Scriptingrp210Elements:InstanceUID="24.00.00.00.00.00.00.00.
                                              00.30.00.00.00.00.00.00.00">
      <rp210Elements:ScriptingKind>Script</rp210Elements:ScriptingKind>
      <rp210Elements:ScriptingText>Student 1 sleeps on the desk.
         </rp210Elements:ScriptingText>
   </DMS1:Scripting>
</rp210Elements:ScriptingSets>
…
```



	= rp210Elements:InstanceUID	{} extension_rp210Elements:MaterialStartTrueDate-Time	{} r...	{} rp210Elements:ShotDescription	{} rp210Elements:S	{} rp210Elements:S
1	20.00.00.00.00.00.00.00.40.00.00.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time {} extension_rp21... 01.00.40.01 {} extension_rp21... 01.01.41.13	r...	Teacher explaining the equation written on the blackboard. Student 1 sweats and hold his head with both hands. Painful expression.	Director's note	AJo YK-PK Chor. Drawing at desk - too slow drive.
2	20.00.00.00.00.00.00.00.41.00.00.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time {} extension_rp21... 01.01.41.13 {} extension_rp21... 01.02.27.01	r...	Student 2 is sleeping on the desk. camera moves to Student 3.	Artur's note	Very good, possible slower camera movement.
3	20.00.00.00.00.00.00.00.42.00.00.00.00.00.00.00	extension_rp210Elements:MaterialStartTrueDate-Time {} extension_rp21... 01.02.27.01 {} extension_rp21... 01.03.23.16	r...	Student 3 - the Girl, sits next to her Boyfriend and tries to sit as far from Student 2 as possible. Disgusted expression on her face. Camera scrolls to Student 4.	Asta	No audio track.

Fig. 12. MXF example file for movie-script entries.

REFERENCES

BORDWELL, D. AND THOMPSON, K. 1997. *Film Art: An Introduction*. McGraw-Hill, New York.

CAPLAN, P. 2003/2004. International initiatives is the implementation in metadata standards. In *International Yearbook of Library and Information Management 2003/2004, Metadata Applications and Management*, Facet Publishing, London.

COX, M., TADIC, L., AND MULDER, E. 2006. *Descriptive Metadata for Television An End-to-End Introduction*. Elsevier, Oxford, UK.

CYBERCOLLEGE. 2007. Scriptwriting. CyberCollege Internet Campus, Http://Www.Cybercollege.Com/Tvp006.Htm.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI) 2004. Digital video broadcasting (DVB): DVB specification for data broadcasting. ETSI EN 300 192 V1.4.1, 2004-11.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI) 2004. Digital video broadcasting (DVB): Transmission system for handheld terminals. ETSI EN 302 304 V1.1.1., 2004-11.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI) 2005. Digital video broadcasting (DVB): Specification for service information (SI) in DVB systems. ETSI EN 300 468 V1.7.1, 2005-12.

EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI) 2006. Digital video broadcasting (DVB): IP datacase over DVB-H - Electronic service guide (ESG). ETSI EN 102 471 V1.2.1, 2006-11.

GOLEBIOWSKI, P. 2006. Design of a metadata schema for enabling an automated high-definition film production workflow. In *Proceedings of the EuroITV 2006 Conference* (Athens).

GOLEBIOWSKI, P. 2007. The application of the material eXchange format's descriptive metadata schema in a high-definition (HD) film production workflow. NAMU research group. vol. MSc. Tampere University of Technology.

GOLEBIOWSKI, P., ABRIL, D. L., AND LUGMAYR, A. 2007. Development of a metadata pepository for digital film production metadata based on the Material eXchange Format (MXF). In *Interactive TV: A Shared Experience, TISCP Adjunct Proceedings of EuroITV 2007 Conference* (Amsterdam).

LUGMAYR, A. 2006. Pre-production of NIJINSKI: First digital-workflow, blue-screen and file-based HD film production in Finland. In *Proceedings of the 2006 SIGGRAPH Conference* (Boston, MA), ACM, New York.

LUGMAYR, A., S. NIIRANEN, S., AND KALLI, S. 2004. *Digital Interactive TV and Metadata: Future Broadcast Multimedia*. Springer, New York. http://www.springeronline.com/sgw/cda/frontpage/0,10735,5-175-72-26593988-0,00.html.

MAUTHE, A. AND THOMAS, P. 2004. *Professional Content Management Systems, Handling Digital Media Assets*. Wiley Ltd., Chichester, UK.

MILLERSON, G. 1999. *Television Production*, 13th ed. Focal Press.

MXF. Material eXchange Format (MXF). http://www.mxf.org/, http://www.mxf.org/.

NAMU Lab. www.cs.tut.fi/sgn/namu. PMWIKI. http://www.pmwiki.org/.

SMPTE. Society for Motion Picture and Television Engineers. http://www.smpte.org.
STRAUSS, A. AND CORBIN, J. 1998. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 2nd ed. Sage, Thousand Oaks, CA.
WEBPROPOL. http://www.webropol.com/.
WIKIPEDIA. Wikipedia - The Free Encyclopedia. http://www.wikipedia.org
YOUTUBE. http://www.youtuble.com/.

Received September 2007; revised November 2007; accepted April 2008

PUBLICATION IX

Kybartaite, A., Malmivuo, J., and Nousiainen, J. Developing media rich virtual learning material for biomedical engineering education. In the *Proceedings of the 14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*, Riga, Latvia, 16.-20.6.2008, pp. 421-424.

Developing Media Rich Virtual Learning Material for Biomedical Engineering Education

A. Kybartaite, J. Malmivuo and J. Nousiainen

Ragnar Granit Institute, Tampere, Finland

Abstract — **Learning materials for the European Virtual Campus for Biomedical Engineering (EVICAB) have been developed and are available in different formats, e.g., text based material delivered as HTML or PDF documents, animated material, electronic text book, audio and video based material. Video based material is a multimedia application with considerable promise for teaching and learning in the higher education. Video lectures have been produced and tested as a learning tool in EVICAB. The preliminary findings support further developments of the video based material for the Virtual Campus for Biomedical Engineering.**

Keywords — **Biomedical Engineering, e-Education, Video Lectures.**

I. Introduction

A critical goal of biomedical engineering education is the introduction of the students to some of the techniques necessary to apply engineering problem solving to living organisms and systems [1]. Educational programs in the field of biomedical engineering had their origins in the 1950s as several formalized training programs were created [2]. By 2005, more than 200 universities of applied science, polytechnic schools, academies and other institutions in Europe offered educational programs in biomedical engineering at all academic levels [3]. The survey conducted in 2006 revealed that about 9% of biomedical engineering related educational centers around the Europe already provide or plan to provide distance courses [4]. Distance teaching and learning (also electronic, virtual, Internet-based, web-based, computer-mediated or mobile) is seen as a future trend in the higher education [5].

As biomedical engineering is a relatively new field of study, not all universities, and especially newly established institutes in biomedical engineering are able to develop and provide a high quality up-to-date teaching and learning materials. Distant, open and free virtual learning environment could offer a possibility to access a high quality learning content for all students and make the teaching and learning not limited by time, place or pace. European Virtual Campus for Biomedical Engineering (EVICAB) is the solution for that.

EVICAB started in January, 2006 as the European Commission funded project with the aim to develop, build up and evaluate sustainable, dynamic solution for virtual mobility and e-learning in the field of biomedical engineering and medical physics [6].

Several different modalities have been used to develop the learning content for EVICAB: (1) text based material delivered as HTML or PDF documents; (2) hypertext material connected text, multimedia and exercises in a meaningful way; (3) animated material enriched text-oriented material by animations and made the content and appearance more interesting; (4) electronic textbook material followed specific textbook; (5) audio based material enhanced text transcription of the lectures; (6) video based material connected face-to-face classroom course with recorded lecturer speaking and presentation for illustration.

Video based material is a multimedia application with considerable promise for teaching and learning in the higher education [7]. The main areas where the video based material is especially effective are: (1) to grasp students' attention and motivate them to learn; (2) to provide highly realistic depiction of situation which students would not otherwise have the occasion to see e.g., medical procedure; (3) to watch again/ later recorded (videoed) live face-to-face lectures.

Our gathered experience when developing video lectures for biomedical engineering is presented in this paper.

II. Materials and methods

A. Theoretical approach: Modeling video lectures

"The aim of teaching is simple: it is to make student learning possible". While the aim is simple, the process is complex [8]. In order to make the virtual education more acceptable by lecturers and students we reviewed related learning theories (Table 1).

The reviewed learning theories support virtual education, e.g., by promoting more self reliance among students, following principle of knowledge construction, supporting different types and levels of learning, including multimedia and video based material in education.

Alexei Katashev, Yuri Dekhtyar, Janis Spigulis (Eds.): NBC 2008, Proceedings 20, pp. 421–424, 2008
www.springerlink.com

Table 1 Connecting learning theories to virtual education

Theory/ Model	Key issue
Paivio's Dual Coding Theory (1986)	Postulates that both visual and verbal codes for representing information are used to organize incoming information into knowledge that can be acted upon, stored, and retrieved for subsequent use. [9], [10]
Severin's Cue Summation theory (1967)	States that learning is increased as the number of available stimuli is increased. The stimuli provided on different channels have to be relevant to each other or the distraction would cause a decrease rather than an increase in learning and retention. Deals specifically with learning and retention in a multimedia environment. [9]
Atkinson-Shiffrin Model (1968)	Proposes multi-store or multi-memory model for the structure of memory. It states human memory is a sequence of three stages: (1) sensory memory, (2) short-term memory, (3) long-term memory. [10]
Baddeley's Theory of Working	The model is composed of three main components; the central executive which acts as supervisory system and controls the flow of information from and to its slave systems: the phonological loop, visuo-spatial sketchpad, and episodic buffer. The slave systems are short-term storage systems dedicated to a content domain (i.e., verbal and visuo-spatial). [10]
Sweller's Cognitive Load Theory (1988)	Refers to the load on working memory during problem solving, thinking and reasoning (including perception, memory, language, etc). [9], [10]
Wittrock's Generative Learning Theory (1989)	Promotes less reliance on professor's lectures while simultaneously creating more self-reliance among students. [10]
Mayer's (SOI) theory of active learning	States that the promise of multimedia learning is that teachers can tap the power of visual and verbal forms of expression in the service of promoting student understanding.[10]
Constructivism	States that: (1) knowledge is constructed, not transmitted, (2) prior knowledge impacts the learning process, (3) initial understanding is local, not global, (4) building useful knowledge structures requires effortful and purposeful activity. [11]
Gagne's Information Processing theory	Stipulates that there are several different types or levels of learning. The significance of these classifications is that each different type requires different types of instruction. Gagne identifies five major categories of learning: verbal information, intellectual skills, cognitive strategies, motor skills and attitudes. Different internal and external conditions are necessary for each type of learning. [9], [10]

The application of video based material in education is not a new endeavor. A projects of combination of recorded lectures and accompanying presentations available via the WWW have been developed by several institutions, e.g., Tutored Video Instructions, eClass, eTeach, Webcast Berkeley, MIT Open Course Ware, Videolectures.NET, Free video lectures. Many more examples are available on the WWW. Based on these examples we defined advantages and disadvantages of the video lectures (Table 2 and 3).

Table 2 Advantages of the video lectures

Allows grabbing students' attention and presenting information that is easy to absorb.
Provides high effect for students' motivation, training and instructions.
Helps to comprehend hard-to-understand concepts and engage in the learning process.
On-campus and off-campus learners can participate in the same learning program.
Provides flexibility for choosing learning place, pace and time.
Provides flexibility to use different equipments, gadgets for learning.
Provides possibility to adopt more flexible learning patterns.
Provides possibility to see recorded lectures given by eminent professor who would not be able to travel to a higher institution more than once.
Offers possibility to become self-sufficient learners.
Students may watch video lectures before attending workshop so that material contained in it might be explored in depth.
Students can better prepare for assessment.
Students can watch video over again until the skill has been mastered.
Students can stop, start and rewind the video to address their specific needs.
Students can watch video lectures to enrich their learning notes.
Allows students to catch up if they miss a face-to-face lecture.
Learning material can be accessed and transferred very fast.

Table 3 Disadvantages of the video lectures

Technical problems, e.g., computer access or Internet connection might be limited.
Quality issues.
Viewers are less forgiving of the lecturer's minor mistake and audience disruption when watching video lectures.
Re watching video lectures can become dull and repetitive learning process.
Students might see video lectures as the only source of knowledge, this could remove students' need to consult other sources, and hence reduce the opportunity to develop as individual learners.
Fast accessing of learning material might diminish the importance of constructing knowledge.
No direct interaction with lecturer, no possibility to ask direct questions.
Video lectures can have adverse effect for attendance.
Technology, e.g., software for producing video lectures is not yet mature.

In order to utilize the advantages and to find solutions for the disadvantages we implemented a practical model to develop video lectures.

B. Practical approach: Model to develop video lectures

A video lecture is a combination of recorded live lecture, accompanying sound and synchronized presentation. It transmits information, encourages reflection, and promotes dialog. There are different approaches for producing video lectures, e.g., videoing lecturer, capturing his speech and displaying all information in one frame; videoing lecturer and displaying presentation along site in a separate frame or recording lecturer's voice and synchronizing with a presentation or graphical information, etc.

The process of developing video lectures has several steps: (1) research on the related technologies including software and hardware, (2) research on the lecture, its content, duration, presentation type, (3) test of the technologies in the real environment, (4) recording video lectures, (5) production of the video lectures including edition and synchronization of video, audio files and presentation, segmenting into easy to absorb parts, arranging table of content, (6) publishing via the Internet, web editing and web serving, (7) providing supporting information, e.g., computer or software requirements in order to access video lectures. The quality of video lectures depends on each step.

The step of production of video lectures for EVICAB was an experimental process. We started by using Synchronized Multimedia Integration Language (SMIL). SMIL code was provided by Hypermedia Laboratory in Tampere University of Technology. The benefit of the code was the possibility to change the lay-out, table of content and size of frames in the video lectures. These features are quite limited in commercial software. Despite that we faced the disadvantage: video lectures were viewable only with Real Player. As Flash Player is more and more used to deliver rich media content with video, graphs and animations we decided to use commercial software [12] and produce video lectures in the flash format. All video lectures were produced in the same way after experimenting and testing.

III. Results

A. Learning materials for EVICAB courses

EVICAB courses are composed of several elements and learning materials, e.g., textbook, e-book, quizzes, virtual lab works, assignments and video lectures. Five courses have been created which include video lectures. They are divided into three groups (Fig. 1). The levels of video lectures vary as introductory, middle or advanced. Bioelectromagnetism lectures can be presented as an example; they are supported by textbook, e-book, and quizzes for self-evaluation. Students can refer to the type of the learning material which is the most convenient for them.

The elements that make video lectures, i.e., audio, video recordings and presentations could be used as reusable learning objects (RO) by other instructors. A common bank for ROs could be created and assessable by permission of the authors.

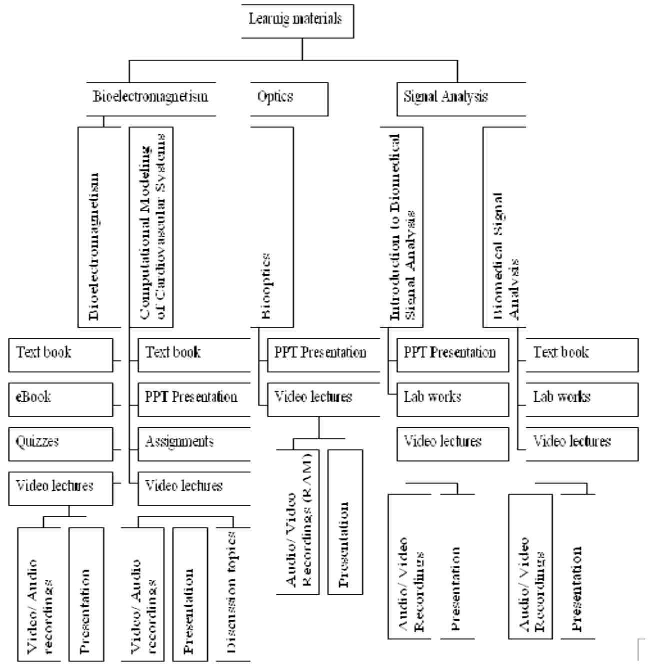


Fig. 1 Learning materials for EVICAB courses

B. Evaluation of the video lectures

The preliminary evaluation of video lectures was performed. It was important to know students' opinions for further developments. The evaluation was based on the questionnaire form. Traditional five-point Likert scale was used to evaluate the usefulness, technical quality, and pedagogical value (Table 4). 18 students, who participated in Bioelectromagnetism course, Tampere University of Technology, 2007 autumn, provided their opinions. The course was available as traditional classroom activity or via virtual learning environment.

The evaluation also revealed that approximately half of the responded students spent most of their study time for attending traditional classroom activities and the other half preferred virtual learning activities, e.g., studying video

Table 4 Average evaluation of the video lectures (by the students)

Usefulness of the video lectures	4,29
Technical quality of the video lectures:	
• Audio quality	3,86
• Video quality	4,07
• Presentation	4
Pedagogical value	4,14

The used scale was from 1 to 5, where 1 meant satisfactory evaluation and 5 - excellent evaluation.

lectures, e-book, making virtual assignments. In addition, we inquired what students expected from the e-material? Most of all, students expected (1) animations that would enrich text-oriented learning material, (2) clear instruction in written format, and (3) learning material in video format. These expectations approved that students accept video lectures and encouraged for the further developments.

IV. Discussion

We compared two learning environments in terms of the outcomes perceived by the students, i.e., results of the final exam of the students who participated in the traditional class activities and who studied video lectures with supporting materials via the virtual learning environment. The summated results showed that independent whether the students participated in the traditional class activities or used video lectures, learning outcomes were almost the same.

The combination of audio + video + presentation was well accepted by students in terms of usefulness, technical quality and pedagogical value (average evaluation was 4). The main reason, we see, why a low number of students used video lectures was the fact that students were not familiar with the video lectures. Still, more than half of the responded students (61%) preferred traditional classroom activity as the only learning method. Technical limitations could also discourage students to watch the video lectures, e.g., slow Internet connection or personal computer properties.

We noticed that more students become interested in e-learning activities, including video lectures. Thus future improvements are needed. They should focus on capturing, integration and access processes. In the video capture process, a system should be able to support generalized capture of the lecture materials without any extra instructor effort. The integration of video, audio and graphical presentation should be smarter; e.g., more semantic linking of the data. The access of video materials should support generalized replay, i.e., start, stop or rewind the video to address a specific need, rather than just showing the static result. Also the access interface could increase the value of video lectures, e.g., adding possibility for collaboration, interactive communication, discussion, links to the other related sources of information, subtitles in a native language, etc.

V. Conclusion

The idea behind video lectures is not to substitute a class activity or to eliminate the lecturer but to support and augment the teaching and learning process for biomedical engineering. Pedagogically based, virtual learning material taking advantages of developments in technology and appropriate learning theories suggests that students should be able to achieve higher learning outcomes.

Acknowledgment

The work has been supported by the eLearning Programme of European Commission.

References

1. P.D. Schreuders, A. Johnson. A System Approach for Bioengineering. Intern. Journal of Engineering Education, 1999. 15(4): p.234-248.
2. P. Benkeser. Biomedical Engineering Education. Encyclopedia of Medical Devices and Instrumentation. 2006
3. Biomedea. Criteria for the Accreditation of Biomedical Engineering Programs in Europe, 2005
4. E.G. Salerud, H. Petersson, M.A. Ilias. European Biomedical Engineering/ Survey Report of Existing and Planned BME Distance Courses in Europe. EVICAB report, 2006
5. P. Pasternack, r. Bloch, C. Gellert, M. Hölscher, R. Kreckel, D. L Ewin, I. Lischka, A. Schidberg. Current and Future Trends in Higher Education/ Summary.
6. EVICAB at www.evicab.eu
7. J.Whatley, A. Ahmad. Using Video to Record Summary Lectures to Aid Student's Revision. Interdisciplinary Journal of Knowledge and Learning Objects, 2007, 3
8. S. Magennis, A. Farrell. Teaching and Learning Activities: Expanding the Repertoire to Support Student Learning. In Emerging Issues in the Practice of University Learning and Teaching, 2005 at: www.aishe.org/readings/2005-1/
9. P. Kaur, H. Atan, S.F. Fong, R.M. Idrus, H. Dzakiria. The Combination of Different Modalities in the Web-Based Learning Environment: A Comparative Analysis of the Perceptual Instructional Outcomes. 2005, Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies.
10. R. Mayer. Multimedia Learning. 2001, Cambridge University Press.
11. Constructivism at: http://srri.umass.edu/topics/constructivism
12. Camtasia Studio at: http://www.techsmith.com/camtasia.asp

Author: Asta Kybartaite
Institute: Ragnar Granit Institute/ Biomedical Engineering Department, Tampere University of Techn.
Street: Korkeakoulunkatu 10
City: FI-33720 Tampere
Country: Finland
Email: asta.kybartaite@tut.fi

PUBLICATION X

Kybartaite, A., Nousiainen, J., and Malmivuo, J. Evaluation of students' attitudes toward virtual learning objects for biomedical engineering**.** *IEEE Multidisciplinary Engineering Education Magazine (MEEM)*, vol. 4, no. 4, pp.102-108, 2009.

Evaluation of Students' Attitudes towards Virtual Learning Objects for Biomedical Engineering

A. Kybartaite, J. Nousiainen and J. Malmivuo, *Fellow, IEEE*

***Abstract*— The goal of this paper is to evaluate students' attitudes towards virtual learning objects for biomedical engineering (BME). Students were able to attend traditional classroom lectures, learn virtually, or both. We developed questionnaire to collect students' feedback and analyzed web log-ins. It is envisioned that results of this study will inform the development of the future virtual campus for BME and for other study areas.**

***Index Terms*— e-Learning, educational technology, feedback, quality analysis and evaluation**

I. Introduction

Tertiary education has seen a massive transformation over the last few decades [1], [2]. The goals have changed from teaching facts into helping students to learn how to find relevant information, how to assess it, how to organize different and distributed information into entity, how to engage in critical reflection and dialogue [3], [4]. Meanwhile, learning has moved towards more student-centered [3], problem-based [5], challenge-based [6], or cooperative learning [7]. The practice of using technology to deliver coursework has also created new opportunities for teaching and learning. For example, audio and video records [8], compact and digital versatile disks (CDs and DVDs) [9], personal computers (PCs) [10], iPods [11], Internet and Web 2.0 applications, i.e., wikis, blogs and podcasts [12] have been adapted for educational purposes.

The growing awareness of the importance of innovations in education urges a need to find ways how to evaluate them. However, the evaluation is problematic [3]. Often evaluation of innovations in education is seen through learning outcomes and expressed in numerical values. This might be not reliable due to a small subject pool, students' prior knowledge, motivation, opportunity, access to materials, the Hawthorne effect, i.e., short-term improvement in performance simply as a result of observation [13], time constrains, emotional status, etc., can count on the influences affecting learning [3]. The value of control groups in education evaluation is highly questionable because random allocation of students may address initial systematic differences between experimental and control groups [3]. The simplest measurement of learning outcomes is by examination. Exam results can be showed numerically, thus they cannot measure deep learning and lifelong learning, which must be accepted as ultimate learning goals [3]. Parameters have not been developed yet for measuring deep learning and lifelong learning [14].

European Virtual Campus for Biomedical Engineering, EVICAB, aims to develop, build up and evaluate sustainable, dynamic solution for virtual mobility and e-learning in the filed of BME [15]. This paper presents an outline for evaluation of student's attitudes towards virtual learning objects.

Authors are with the Department of Biomedical Engineering, Tampere University of Technology, PL 692, 33101 Tampere, Finland (e-mail: asta.kybartaite@tut.fi).

II. Literature review

A. Review of Education Evaluation Methods

Literature review revealed a number of different attempts to evaluate innovations in education.

For example, Silius and Tervakari [16] proposed online multidisciplinary evaluation framework for the web-based courses for learners, teachers and researchers to define factors critical in the implementation of training and learning services. The main issues within this framework were usability, pedagogical usability, added value, accessibility and information quality of web-based learning environments.

Shaw and Pieter [17] studied change in teaching strategy and views of students when asynchronous learning networks were implemented. For that purpose they developed online questionnaire. The questionnaire included structured questions restricting responses to a narrow range of alternatives and consisted of 16 statements in either text match or multiple choice formats. The text match questions allowed students to express opinions in their own words and the multiple-choice format consisted of 5 possible responses to the given statement arranged in a Likert format.

Ma et. al., [18] investigated whether virtual initiatives succeed. They suggested analyzing critical success factors in virtual education information system. Authors adopted measurement approach that recognized two types of value measures. Direct measures, which measure benefits, accrued by users and their organization units, and indirect measures, which indicate that the system is useful, based on patterns of usage and diffusion. The set of direct measures was derived from the knowledge of benefits derived in academic environments. The set of indirect measures came from the work of Rockart and DeLong [19] as well as others.

Brotherton and Abowd [20] applied four different methods for obtaining information what learning material students were accessing within educational capture system, also how, when, why and where they were accessing. These methods included web-login analysis with session tracking, questionnaires, controlled experiments, and classroom observations.

Donoghue [21] assessed what opportunities and tangible assets online learning resources may offer to and require from university and student body. The author used illustrative case-examples and post-course surveys. Survey questions were categorized into six specific areas of focus, i.e., student skills upon enrolment, technology availability, perception of different learning environments, value-added attributes of an online learning environment, pedagogy, and future course development. Questions were largely presented through a Likert-type format allowing interrogating quantitative and decision/ acceptance data. The survey concluded with open-ended comments for non-defined aspects. Survey forms were sent to students by email, with the choice of return by email attachment or printing and posting, if anonymity was desired.

Lee et. al., [2] analyzed how students were prepared for newly developed virtual learning environments by adapting and broadening the framework of technology acceptance model (TAM) developed by Davis, Bagozzi, and Warshaw (1989) [22]. The model proposed that perceived usefulness and perceived easiness are influenced by external variables (e.g., educator authority, university policy) and will influence attitude towards using and actual use of computers (also virtual learning environments). The model was realized through administrating questionnaire to the students. Responses were scored on four-point Likert-type scale ranging from 1-strongly disagree to 4-strongly agree.

Wegner et. al., [23] investigated the impact of Internet-based delivery system on student learning. Students were allowed to self-select into either the traditional classroom section or into the experimental Internet-based section. Problem based learning model was selected to provide comparable learning opportunities. In order to provide conclusions, students' achievements in 100-point exam and satisfaction survey results were compared.

Platteaux and Dasen [24] studied how different students perceive e-learning and what elements made the learning process efficient or not, easy or difficult. Authors gathered quantitative and qualitative data by means of questionnaire and discussion with the students and teacher. The questionnaire was distributed to the students during the last face-to-face moment of the course. The course followed blended learning model.

Aitken and Tabakov [25] designed evaluation to investigate views of student users and training experts on e-learning material using Kirkpatrick's [26] four levels model of evaluation, i.e., reaction, learning, behavior and results. Authors evaluated views of student users at levels 1 (i.e., students' perceptions) and 2 (i.e., knowledge/ skills gained). Data was collected by means of questionnaires.

B. Questionnaires for Obtaining Feedbacks

Students' feedbacks have been recognized as one of the most important considerations when evaluating teaching and learning [27]. Literature review revealed that students' feedbacks are often obtained by means of questionnaires. Other methods, e.g., interviews or classroom observations maybe useful as well, thus, questionnaires have two advantages over others: 1) provide opportunity to obtain feedbacks from the entire population of students, and 2) allow documenting experiences of the students population in more or less systematic way [28]. The process of obtaining feedbacks by means of questionnaires is relatively simple and convenient for both teachers and students; and has been accepted as a matter of routine in many institutions [28]. Due to that reason feedbacks may not always be regarded as a serious matter by those who are involved [28].

This type of evaluation is most often performed at the end of the course and frequently is linked to future arrangements and improvement decisions [29]. There are a number of studies that analyze the value of feedbacks [30], [31]. Aleamoni [32] stated that data obtained from feedbacks provide instructors with first-hand diagnostic information of the accomplishment of educational goals, level of satisfaction and influence of various course elements. Constructively used feedback data can be beneficial for students through improved teaching and learning environment. Also may provide information for the future students when selecting course units or teachers. Administrators may benefit through more accurate representation of students judgments in the decision making process [32].

There are a number of published discussions about ways how to design questionnaires. Krosnick [33] states that there is no best way; thus different phrasings or formats might yield different results. Schwarz [34] contributes that measurement of behaviors and attitudes are strongly influenced by survey instrument features, e.g., minor changes in question wording, format or context can result in major changes in the obtained results. At least five key issues [35] should be considered when designing questionnaire: 1) characteristics of different types of questions, 2) their advantages and disadvantages, 3) good practice in designing questions, 4) good practice in designing format and sequence of questions, and 5) clear instructions.

Once a questionnaire is created it is advised to try it out with a small sample similar to the potential respondents. Pretesting of pilot questionnaire may reveal ambiguities, poorly worded questions, questions that are not understood, unclear choices or clearness of instructions.

Statistically significant findings indicate that students' motivation to provide feedbacks depend upon: 1) the importance to them of improving the value of the current class and that of future classes and 2) the expectation that their evaluative feedback would lead to increased value for them and for future students [29].

Göb et. al., [36] states that the major criteria when analyzing questionnaires should be simplicity, availability, clarity, exactness and information value. Methods like principle component analysis, factor analysis, correlation analysis, t-testing or ANOVA allow describing simplicity and availability. Methods to define clarity and exactness are based on normality assumptions. These assumptions remain mostly undiscussed. Methods for retrieving information value are summing or averaging scores. However, summing or averaging may hide or distort information. For example, strong agreements and strong disagreements may be averaged, providing a misleading impression of average agreement [36].

III. Case Study

The purpose of this study case was to collect, analyze, interpret and compare attitudes of students who participated in the course, which was delivered as a traditional classroom course and also was available as a virtual course. Students' attitudes were analyzed on the basis of their responses to the questionnaire. These attitudes were important since considerable amount of time and effort is usually spent for improving traditional classroom courses and developing virtual courses, generally with little consideration of attitudes of the students.

The international course on Bioelectromagnetism (BEM) has been implemented at Tampere University of Technology (TUT), autumn 2007, 2008, 2009 and Helsinki University of Technology (HUT), spring 2009. Despite the different locations and time, the course content, teacher and requirements remained the same. Instructional materials in the course were: classroom lectures, exercises, video lectures, e-Book, and individual assignments. In addition, Internet examination was arranged. Digital material was available from the virtual campus, EVICAB. Students could make free choices individually whether to attend traditional classroom lectures or to follow them virtually as video lectures on the Internet, or both. Internet examination was compulsory for all students [37], [38].

Altogether 66 students, out of 71, who participated in BEM course and took Internet exam, provided feedbacks by answering the questionnaire. After finishing exam work they had time to reflect individually on the questionnaire, respond and return feedbacks to the course assistant. Students had different international and educational background, e.g., seeking university degree, international, visiting or exchange students (Fig.1).

The pilot version of the questionnaire (autumn, 2007) included 12 questions. Later the form was improved; 20 questions were included. Questions were closed- and opened-ended; students had possibility to express opinions by

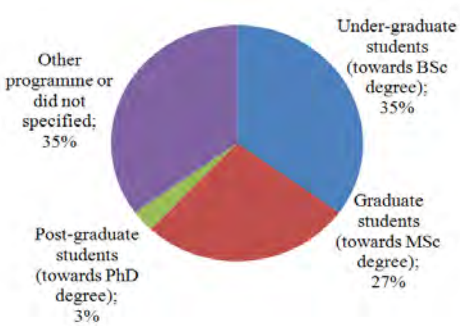


Fig. 1. Educational background of students, who participated in the course and provided feedbacks.

selecting one or more answers from the multiple-choice questions and to comment in own words. Some answers to the questions had grading system – Likert scale from 1 to 5; where 1 – strongly disagree (or not useful), 5 – strongly agree (or very useful).

IV. Results

A. Questionnaire Results

Practical Issues. Based on reported amount of study time spent for this course, students were grouped into traditional classroom students and virtual class students (Table 1). Students who spent equal amount of time for traditional classroom and virtual class activities were ascribed as blended class students. Totally 35% of students spent more than half of their study time for attending traditional classroom lectures and exercise sessions; 21% of students spent half of their time for virtual learning, i.e., watching video lectures, reading e-book, doing online quizzes; and 44% of students spent equal amount of time for both - classroom lectures and virtual learning.

Students had different opinions about usefulness of instructional materials in the traditional classroom course and virtual course (Fig 2).

When students were asked what learning method they prefer as the only learning method, 67% of students preferred traditional classroom. The most common reason was that it allows interacting, i.e., to ask questions, comment and discuss with the lecturer and class participants. As the two key points in the traditional classroom lecture students indicated the lecturer – his/ her capability to present material, to raise the interest in the topic, and the content – how significant it is for the students themselves. Still 30% of students preferred virtual class on the Internet because it 'offers possibility to revise concepts', 'allows watching at any time and taking brakes', 'everyone can attend'. Thus 3% of students were not sure which learning method is the best for them.

TABLE 1
Groups of Students

Group of students	Conditions
Traditional classroom students	More than 50 % of study time spent for: - attending classroom lectures, - attending classroom exercises, or attending classroom lectures + exercises
Virtual class students	More that 50% of study time spent for: - studying from video lectures, - studying from e-book, or - studying from video lectures + e-book
Blended class students	Equal amount of study time spent for traditional classroom and virtual class

Seven different elements supporting learning materials were available for the students, i.e., learning materials in video format, learning materials in audio format, instructions in written format, animations, downloadable materials (to PCs, iPods, media phones), exercises and queries on the web, and virtual comments on learning topic. Students had possibility to test these elements within EVICAB. In addition, other elements like, self-assessing tests and quizzes, video games based on learning topic, subtitles in native language have been considered. Thus, so far, students were able only to anticipate their usefulness (Fig.3).

The most useful elements based on students' opinions were learning materials in video format, animations and instructions in written format. Students anticipated that self-assessing tests and quizzes would be useful to some extend (Fig.3).

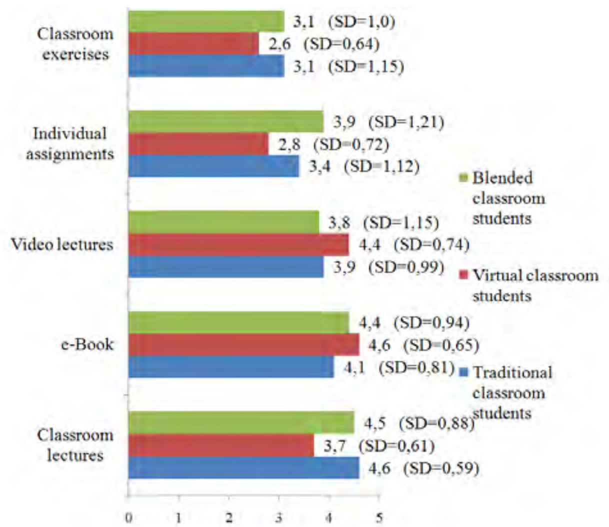


Fig. 2. Traditional classroom, virtual class, and blended class students evaluated usefulness of instructional materials of the course. Evaluation scale was from 1 (not useful) to 5 (very useful). The chart presents average values and standard deviations.

Based on students' answers, the most useful resource in virtual course would be lecture handouts then virtual demonstrations, virtual presentations and lectures, virtual laboratory works and virtual exercises.

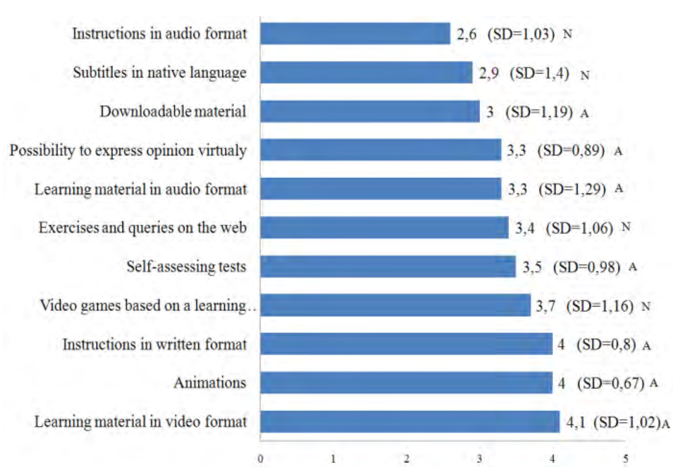


Fig. 3. Usefulness of learning elements presented as averages and standard deviations. Evaluation scale was from 1 (not useful) to 5 (very useful). A: Learning elements were available in virtual campus. Students had possibility to test them. N: Learning elements were not available in virtual campus. Students anticipated their usefulness.

When developing virtual campus, we were interested what modern technologies may be used to support virtual education. Therefore we inquired students what devices do they use to store and playback digital recordings. The majority of students, i.e., 60% use only PC, 38% use PC and other devices, e.g., iPod/ iPhone, MP3 player, and cell phone (Fig.4).

Digital format of a document or a file is important when choosing a device for accessing it. Therefore it was important to get information what is the most common recording format used by students. Students preferred downloading materials to their

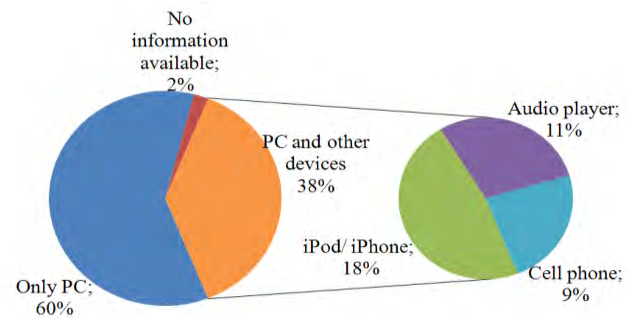


Fig. 4. Devices used by students to support learning process.

PCs (63% of answers). Downloading files can happen at low speed but once they are transferred they can be played multiple times and do not require Internet connection. Less of the students (35% of answers) like to watch streamed recordings from the Internet because it requires constant Internet connection. Podcasting and vodcasting were still quite new technologies for students (2% of answers).

We were able to ask directly 48 students whether they followed video lectures of BEM course and 83% of students followed video lectures on PCs and 6% of them on iPods. Thus, 11% of students did not follow video lectures at all only attended traditional classroom lectures.

Those who followed video lectures evaluated audio and video quality, presentation and pedagogical value of video lectures within the scale from 1 (low quality) to 5 (very high quality). Results showed that the high quality of video lectures motivated students to follow them, i.e., audio quality – 3.8 poits (out of 5), video quality – 4, presentation – 4, pedagogical value – 4.

It was important to find out what problems students may experience when accessing and streaming video lectures on PCs, downloading and watching video lectures on iPods or media phones. The problems were summarized in Table 2.

The main reason why students followed video lectures was to revise and review course material (31% of answers). In addition, students found useful to watch video lectures before exam (26%) and when not being able to attend classroom lectures due to other commitments (25%). About 10% of answers stated that video lectures were useful when not being able to attend classroom lectures due to disability or health problem. About 6% of answers indicated that video lectures were useful for studying on the go, e.g., when traveling by train, waiting bus, spending time in waiting halls, etc. Only 2% of answers stated that video lectures were preferred more than face-to-face lectures.

Since there were students who did not follow video lectures we were interested why. The main reasons were that students preferred traditional lectures more than recordings (53% of answers), watching video lectures became dull and repetitive process (18%), and due to technical limitations, e.g., PC, player or Internet connection speed discouraged watching video lectures (11%). Minority of students (10%) was not familiar with the idea of video lectures and some (8%) were not satisfied with the quality of video lectures.

TABLE 2
COMMON PROBLEMS WHEN ACCESSING VIDEO LECTURES

Method of accessing video lectures	Common problems
Accessing and streaming video lectures on PC	1) Slow Internet connection 2) No Flash player installed 3) Wrong player, e.g., Real player 4) PC properties, e.g., 'old' laptop 5) Difficult to find right files with video lectures on website
Downloading and watching video lectures on iPod	1) Do not have own iPod 2) Do not download files to my PC
Downloading and watching video lectures on media phone	1) Too large files 2) Do not have own suitable media phone

Students' Suggestions. Students suggested several improvements for video lectures and e-book as for the learning tools. Suggestions for video lectures were:

- More detailed dynamic table of content for each video lecture.
- Good quality and control mechanism.
- An option to download video lectures.
- More informative text.
- Good and clear presentation.
- Explanation step by step so that no need to face difficulties when finding and accessing each lecture.
- Adding fast forward button so that the video can be heard at a faster rate.
- To have main points in native language (e.g., as subtitles).
- More animations and links about the subject.
- Test or quiz at the end of each video lecture.

The suggestions for e-book were:

- Better graphics and animation.
- Separate theoretical and practical material.
- Add page numbering that corresponds with subject index.
- Better search option that could be able to link topics.
- Availability in PDF format.
- Links from the e-book to corresponding video lectures.
- Summaries of chapters.
- Updated interface.
- More animations.

Video lectures contained presentation, recorded lecturer and narration, dynamic table of content, start, stop, forwarding and reversing buttons. Few students did not realize that forward and reverse buttons are synchronized with dynamic table of content, i.e., selecting topic from dynamic table of content it is possible to get to that presentation part where it is discussed in video, so it is not necessary to watch the whole lecture if one is interested only in a certain topic.

Open book Internet examination was quite a new endeavor. Students evaluated it as 3.9 (out of 5) and provided comments, which were grouped into positive and negative.

Positive comments were:

- Internet exam was not memory based.
- Was focused on understanding but not on mechanical learning.
- References were available.
- It was possible to access exam anywhere.
- Served as a learning process (possible to enhance knowledge even during the exam).
- Knowledge application was like in the real world.
- Good change.

Negative comments included:

- Boring to read from the screen.
- Traditional exam was less stressful.
- Necessary to read material in advance to know where to take references from.
- Open book Internet exam provided too many reference materials.
- Possible to copy and paste answers without understanding or knowing the meaning.
- Not absolutely sure that exam answers will end up in correct place.
- Internet connection problems or related technical issues might suddenly ruin the exam.
- Slower to write with computer than by hand.
- Not sure how well it tests knowledge.

Communication in Virtual Class. Classroom interactivity is a critical component of teaching and learning [39]. Especially it is important in virtual environment due to the distance between educator, students, and peers. Based on previous experiences students anticipated how social communication ways and technologies embedded in a course support their learning. Majority of students' answers showed that face-to- face meetings are the most acceptable way of communication (33%), then e-mailing (24%), group meetings (15%), online forum (12%), instant messaging (6%), wiki (3%), blog (3%), audio/ video conference (2%) and phone/ Internet phone (2%).

As students were able to choose how to participate in the course, it was important to find out whether availability of video lectures motivated them to skip traditional classroom lectures. The most common reason why students skipped traditional classroom lectures was another class at the same time. About 17 % of answers stated that availability of video lectures encouraged them to skip the class (Fig.5).

The language is considered to be one of the educational challenges. It is complicated to deliver education in one language so that it is acceptable by the majority of international students. Thus students' feedbacks confirmed that the English language is suitable for the virtual learning but still 25% of students would like to have some help in a native language, e.g., subtitles. None of the students totally denied that English is suitable for virtual education.

Students' Experiences in Virtual Learning. The use of information communication technology (ICT) to enhance teaching and learning processes has been practiced for a number of years [18]. Therefore we inquired what experience do students have in virtual learning: 40% of students participated in

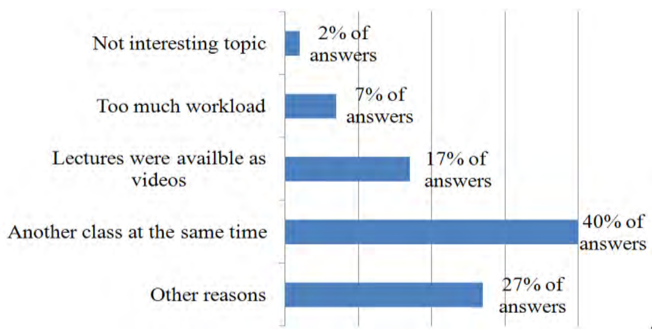


Fig. 5. The most common reasons why students did not participate in traditional classroom lectures.

virtual course earlier, 30% of students did not participate in any virtual course before, 20% of students did not participate but mentioned that would like to, 10% of students did not participate and mentioned that they are not interested to learn virtually.

To conclude their feedback students provided open-ended comments for non-defined aspects, for example: 'I found very useful to read the book and watch lectures when I could not take part in some lectures.' 'Good video material.' 'While watching the video lectures, it would be very helpful to check somewhere all special words and basic idea of the phenomena or equation which the professor mentioned in the video.' 'All the material was good I think. If there were no traditional lectures I would have used virtual material more.' 'It is a good concept and must be implemented for almost all courses in BME with availability of online lectures.' 'Virtual material is nice extra for lectures but do not replace them.' 'It would be nice to have more courses organized in a similar way. More online video lectures would be nice too.' 'There should be more videos of actual operations for inserting pacemakers, setting up ECG etc., that would make the course more interesting. "Video lectures were really good, sound and the slides combined were a really good idea.'

B. Comparing Exam Results

Students who responded to the questionnaire were able to choose whether to be anonymous or not; only 32% indentified their names. So it was possible to compare their preferred learning methods and final examination results. We separated these 32% of students as traditional classroom, virtual class and blended class students. Their final exam results appeared to be very similar: average exam results of all students was 2.77 (out of 5); average exam results of traditional classroom students was 2.83; average exam results of virtual students was 2.85; average exam results of blended class students was 2.60.

C. Web Log-ins Analysis

Log-ins analysis provided information when, from where and how (e.g., by PC, downloaded for iPod or media phone) virtual material was accessed.

Virtual users assessed learning materials every weekday, average number of visits was more than 40 per day, from all over the world, e.g., Austria, Australia, Brasilia, China, Columbia, Germany, India, Indonesia, Italy, Mexico, Norway, Peru, Singapore, etc.,

Web log-ins allowed to clarify what type of video lectures remote users accessed the most. Video lectures for PCs were accessed the most, then video lectures for iPods and video lectures for media phones.

Most of the users accessed virtual materials with Firefox browsers using Windows operating machines. This information was important as not every browser on every operating system is able to correctly decode video files.

V. Conclusions

In this paper we presented the longitudinal study for evaluating students' attitudes towards virtual learning objects for BME. Quantitative and qualitative data was collected by means of questionnaire and web log-ins system. Most of the obtained data was expressed in numerical values. Our main findings show that students accept and progressively become more interested in virtual education. In general, they say that 'it would be nice to have more courses organized in a similar way'.

Those students who were able to attend traditional classroom lectures were still interested in virtual learning. So those who were not able to attend traditional classroom lectures might found virtual learning even more useful.

Students who provided feedback were university students but log-ins analysis revealed that also users world-wide were accessing learning material. Therefore, virtual education did not replace or eliminate education on the university scale but supported and augmented on the global scale.

Nowadays technologies for virtual education are available and relative user friendly. For example, it is possible to produce video lectures and deliver them globally. Anyone can access them.

The number of people who have access to the Internet is increasing and nowadays most of university students' use Internet for their studies. Technologies might cause some problems, e.g., slow Internet connection, video files and devices compatibility, but advancements in the field are developing globally and very fast providing new and modern solutions.

Findings of this study show that students' attitudes towards virtual learning objects for BME are positive. Thus the development of learning objects should continue considering students' attitudes.

REFERENCES

[1] D. Laurillard, *Rethinking University Teaching: A Conversational Framework for the Effective Use of Learning Technologies*, Routledge, 2001.

[2] J. Lee, N.L. Hong, and N.L. Ling, "An analysis of students' preparation for the virtual learning environment," *The Internet and Higher Education*, vol. 4, 2001, pp. 231-242.

[3] S. Lechner, "Evaluation of teaching and learning strategies," *Med. Educ. Online*, vol. 6, Aug. 2001.

[4] S. Magennis and A. Farrell, "Teaching and learning activities: expanding the repertoire to support student learning," *Emerging issues in the practise of university learning and teaching*, 2005.

[5] M. LaPlaca, W. Newstetter, and A. Yoganathan, "Problem-based learning in biomedical engineering curricula," *Frontiers in Education Conference, 2001. 31st Annual*, 2001, pp. F3E-16-21 vol.2.

[6] T.R. Harris and S.P. Brophy, "Challenge-based instruction in biomedical engineering: A scalable method to increase the efficiency and effectiveness of teaching and learning in biomedical engineering," *Medical Engineering & Physics*, vol. 27, Sep. 2005, pp. 617-624.

[7] D. DeZure and T.J. Marchese, *Learning from change*, Stylus Publishing, LLC., 2000.

[8] A.J. Chandrasekhar and R.N. Price, "Interactive Video in Medical Education," *Proceedings of the Annual Symposium on Computer Application in Medical Care*, Nov. 1989, pp. 1039–1040.

[9] K.A. Eaton, P.A. Reynolds, and M.J. Cox, "Top of the pops - CD-ROM and DVDs in dental education," *Br Dent J*, vol. 204, Feb. 2008, pp. 203-207.

[10] C.C. Kulik and J.A. Kulik, "Effectiveness of computer-based instruction: An updated analysis," *Computers in Human Behavior*, vol. 7, 1991, pp. 75-94.

[11] E.J. Palmer and P.G. Devitt, "A method for creating interactive content for the iPod, and its potential use as a learning tool: Technical Advances," *BMC Medical Education*, vol. 7, 2007, p. 32.

[12] M.N.K. Boulos, I. Maramba, and S. Wheeler, "Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education," *BMC Medical Education*, vol. 6, 2006, p. 41.

[13] S.R.G. Jones, "Was There a Hawthorne Effect?," *The American Journal of Sociology*, vol. 98, Nov. 1992, pp. 451-468.

[14] D. Boud and G.I. Feletti, "The Challenge of Problem-Based Learning. 2nd Edition.," 1997.

[15] J. Malmivuo, "Evicab," *http://ww.evicab.eu*. Accessed May, 2009.

[16] K. Silius and A. Tervakari, "The usefulness of web-based learning environments. The evaluation tool inot the Portal of Finnish Virtual University," *International Conference on Network Universities and e-Learning*, Valencia. Spain: 2003.

[17] G.P. Shaw and W. Pieter, "The use of asynchronous learning networks in nutrition education: student attitudem experiences and performance," *JALN*, vol. 4, Jun. 2000.

[18] L. Ma, D. Vogel, and C. Wagner, "Will virtual education initiatives succeed?," *Inf. Technol. and Management*, vol. 1, 2000, pp. 209-227.

[19] J.F. Rockart and D.W.D. Long, *Executive Support Systems: The Emergence of Top Management Computer Use*, Business One Irwin, 1988.

[20] J.A. Brotherton and G.D. Abowd, "Lessons learned from eClass: Assessing automated capture and access in the classroom," *ACM Trans. Comput.-Hum. Interact.*, vol. 11, 2004, pp. 121-155.

[21] S.L. Donoghue, "Institutional potential for online learning: a Hong Kong case study," *Educational Technology & Society*, vol. 9, 2006, pp. 78-94.

[22] F.D. Davis, R.P. Bagozzi, and P.R. Warshaw, "User acceptance of computer technology: a comparison of two theoretical models," *Manage. Sci.*, vol. 35, 1989, pp. 982-1003.

[23] S.B. Wegner, K.C. Holloway, and E.M. Garton, "The effect of Internet-based instruction on student learning," *JALN*, vol. 3, Nov. 1999.

[24] H. Platteaux and V. Dasen, "How different students perceive e-learning? the case of antiquit@s, an ancient history course," *Conference on New Educational Environments*, Neuchatel: 2004.

[25] V. Aitken and S. Tabakov, "Evaluation of the e-Learning material developed by EMERALD and EMIT for diagnostic imaging and radiotherapy," *Medical Engineering & Physics*, vol. 27, 2005, pp. 633-639.

[26] D.L. Kirkpatrick, *Evaluating training programs*, Berrett-Koehler Publishers, 1998.

[27] A. Holmes and S. Brown, *Internal audit in higher education*, Routledge, 2000.

[28] J.T. Richardson, "Instruments for obtaining student feedback: a review of the literature," *Assessment & Evaluation in Higher Education*, vol. 30, 2005, pp. 387-415.

[29] J. Caulfield, "What motivates students to provide feeedback to teachers about teaching and learning? An Expectancy theory perspective," *International Journal for the Scholarship of Teaching and Learning*, vol. 1, Jan. 2007.

[30] H. Murray, "Student evaluation of teaching: has it made a difference?," *Annual Meeting of the Society for Teaching and Learning in Higher Education*, 2005.

[31] G.S. Goldstein and V. Benassi, "Students' and instructors' beliefs about excellent lecturers and discussion leaders," *Research in Higher Education*, vol. 47, 2006.

[32] L.M. Aleamoni, "Student Rating Myths Versus Research Facts from 1924 to 1998," *Journal of Personnel Evaluation in Education*, vol. 13, 1999.

[33] J.A. Krosnick, "Survey research," *Annu. Rev. Psychol.*, vol. 50, 1999, pp. 537-567.

[34] N. Schwarz, "Self-reports. How the questions shape the answers," *American Psychologist*, vol. 54, 1999, pp. 93-105.

[35] J. Stasko, "Questionnaire design," *http://www.cc.gatech.edu*. Accessed May, 2009.

[36] R. Göb, C. McCollin, and M. Ramalhoto, "Ordinal Methodology in the Analysis of Likert Scales," *Quality and Quantity*, vol. 41, Oct. 2007, pp. 601-626.

[37] J. Malmivuo, "Internet examination," *EVICAB*, 2009.

[38] J. Malmivuo, K. Lindroos, and J. Nousiainen, "Internet examination - a new tool in e-learning," *Mediterranean conference on medical and biological engineering and computing*, Ljubljana, Slovenia: Springer, 2007, pp. 336-337.

[39] K. Siau, H. Sheng, and F. Nah, "Use of a classroom response system to enhance classroom interactivity," *IEEE Transactions on Education*, vol. 49, 2006, pp. 398-403.

PUBLICATION XI

Kybartaite, A., Salerud, G., and Malmivuo, J. Developing practice of e-learning application in biomedical engineering in Europe. *The 3rd International* e*Learning Baltics, eLBa Science Conference*, accepted for publication in the Proceedings, 2010.

Practice of e-Learning Development and Application in Biomedical Engineering Education in Europe

A. Kybartaite[1], E.G. Salerud[2], J.A. Malmivuo[1]

[1]Department of Biomedical Engineering
Tampere University of Technology
Korkeakoulunkatu 3
FI-33720 Tampere
asta.kybartaite@tut.fi

[2]Department of Biomedical Engineering
Linköping University
Campus US
SE-581 85 Linköping
gosal@imt.liu.se

Abstract: E-learning can provide many advantages for Biomedical Engineering (BME) educationt. An increasing number of applications of e-learning urges a need to find methods how to evaluate them. The aim of this study was to investigate how e-learning has been developing so far (during the years 2006-2009) among BME education offering centers in Europe and to make an estimate of its development in the near future. Therefore, three questionnaires have been prepared and sent to BME education offering centers in Europe in September, 2006, January, 2008 and January, 2010. In general, results show that teachers are interested in further developments and implementations of e-learning for BME education.

1. Introduction

Review of e-learning literature [1], [2], [3], [4] reveals that e-learning can provide advantages for Biomedical Engineering (BME) education. There is no single definition for BME, thus, Bronzino [5] suggests that it is *an interdisciplinary branch of engineering that ranges from theoretical, non experimental undertakings to state-of-the-art applications and encompasses research, development, implementation, and operation*. In the article by LaPlaca et al., [6] the BME field is defined as *the result of the merger between traditional engineering disciplines such as mechanical, chemical, and electrical engineering and the biology-based disciplines of life science and medicine in order to improve procedures such as diagnostic testing, noninvasive surgical techniques, and patient rehabilitation and to apply quantitative analyses to biological problems*. In general, the BME field provides solutions, which have to challenge to remain relevant, while society and technologies continuously change. At the same time BME education has to develop, not just to follow but also anticipate the needs of a changing society and their technologies.

According to the World Factbook [7] there are more than 4 billion (2008) mobile cellular phones in use (60% of the population) and more than 1.6 billion Internet users (2008). The fast development of information and communication technologies (ICTs) provides many opportunities for new teaching contexts where e-learning [8], distance [9], network [10], portable [11], mobile [12] or ubiquitous learning [13] offers new learning possibilities both for teachers and students. According to Nagy [14] the term “e-learning” may be considered as an umbrella term describing any type of learning that depends on or is enhanced by the latest ICTs. In general, e-learning is not very precise and is used inconsistently, thus it can be defined as *the use of digital media and communication technologies, and in particular the online environment, to support learning activities* [15]. In order to grasp the meaning of e-learning on the global scale, the previously mentioned words and synonyms were entered into the Internet search engine, i.e., Google. Only for the key word “e-learning” about 91 500 000 hits were found in 0.33 seconds. This proves the huge interest but also the enormous amount of information available about e-learning.

An increasing number of implementations of e-learning applications urge the need to find methods on how to evaluate them. Several related quality assurance systems have been created and are still in the process of development in Europe. For example, the Bologna Process [16] introduces a three-cycle system and invites to consider how to make pedagogy more student-centered and addresses the needs of graduates to be given adequately studies. European Association for Quality Assurance in Higher Education (ENQA) [17] provides Standards and Guidelines for Quality Assurance for the Higher Education. The ERASMUS programme [18] has brought mobility to a wide range of students from different countries and backgrounds. The commonly used ECTS, learner-centered system for credit accumulation and transfer¸ allows seeking for the recognition of what students have learned at home, abroad, in formal education, through self-study or through work experience [18]. In the BME field, BIOMEDEA [19] suggests Criteria for the Accreditation of Biomedical Engineering Programs in Europe. A study by the European Quality Observatory [20] reveals that there also exist practices for quality assessment in e-learning and suggests further developments.

The European Virtual Campus for Biomedical Engineering, EVICAB, has been developed as a platform for common BME e-learning [21]. The objective of the EVICAB project [22] was to develop, build up and evaluate sustainable, dynamic solutions for virtual mobility and e-learning, according to the Bologna process:

i. Mutually support the harmonization of the European higher education programs,
ii. Improve the quality of and comparability between the programs, and
iii. Advance the post-graduate studies, qualification and certification.

The aim of this study was to investigate how BME education centers in Europe implement and has developed e-learning from 2006 to 2009, and to make an estimate of its continuing development in the near future. Therefore, in order to predict the future, we made a multivariate analysis of the BME e-courses. It is anticipated that the results may motivate the planning of future e-learning in BME and become useful in defining educational plans and goals. Therefore, three questionnaires were prepared and sent out to BME education centers in Europe in September, 2006, January, 2008 and January, 2010.

This paper is based mostly on data obtained from the first and second questionnaires. The educational centers were identified from the survey list in the BIOMEDEA report [23] and by inspecting the national BME societies that were published on the World Wide Web (WWW) [24]. The same list of contact addresses was used for all questionnaires, thus during the time some of them discontinued but newcomers were not included. The target group consisted of teachers and programme coordinators, responsible for education by designing courses and / or curricula.

This paper was written in generic manner so that it can serve as a reference or a starting point for any other e-learning initiative having similar goals.

2. Methods

The aim of the first questionnaire "Existing and planned BME distance courses in Europe" was to get information from experiences of other similar initiatives in the past and to prepare for contribution in the harmonization process of e-learning in BME [24]. The questionnaire was prepared in two versions; an extended version was answered by the European Virtual Campus for Biomedical Engineering (EVICAB) members including 23 questions; and a shorter one for other identified and presumable educational centers comprising 16 questions. The questionnaire was structured according to the following sections [24]:

- Practical issues containing information about the e-course duration, workload, operative language, topic and cycle of qualification.
- Internal and external quality assurance revealing whether the courses comply to the standards set by the ENQA or not.
- Student mobility, lifelong learning and transparency revealing the expected nationality and age distribution of the enrolled students. Transparency of educational content and learning outcome were included since it is expected to affect students' choices.
- Supplementary issues such as the interest in pedagogical approach and the promotion of e-courses through the EVICAB platform.

The questionnaire was sent out to a total of 263 persons in April – July, 2006.

The aim of the second questionnaire “Implementing and conducting of EVICAB courses” was to collect information if e-courses were or could be recognized and applied by BME education centers in Europe. The questionnaire included 5 questions and was sent out to the previously identified responders using an online system [25] in December, 2007 – January, 2008.

In the third questionnaire "Existing and planned BME distance courses, application and recognition of BME virtual education in Europe" questions from the previous two surveys were combined. Altogether there were 30 questions. The aim of the questionnaire was to observe the development process in BME e-learning in Europe. It was sent out to a total of 231 respondents using the abovementioned online system [25]. The questionnaire was administered in December, 2009 - February, 2010.

This paper was written mainly based on data obtained from the first and second questionnaires. Due to low number of respondents, the third questionnaire was not considered as sufficient. Results were structured into 5 categories: practical student issues, internal and external quality assurance, students’ mobility, lifelong learning and transparency, application and recognition, and other issues. Data was processed and information was collected into clustered column charts, Figures 1-10. Charts represent percentage distribution of e-courses.

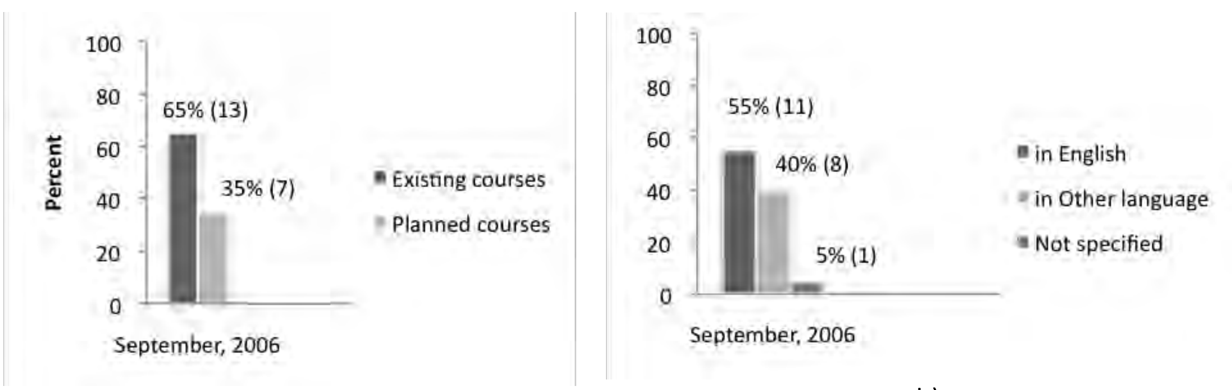
3. Results

3.1 Number of responders

In the first questionnaire we received 62 answers (~23 percent of the asked persons) where 16 answers (~26 percent of the received answers) stated that BME distance courses existed or were planned at a certain university, summing up to a total of 20 e-courses. The second questionnaire received 34 answers and in the third questionnaire we received only 16 answers, where 13 answers informed about existing or planned BME e-courses.

3.2 Practical issues

More than half of BME education centers in Europe have reported on available e-courses and more than half of these e-courses are delivered in English, Figure 1.



a) b)

Figure 1. a) Plot of existing and planned e-courses (indicates the real number of e-courses) b) Histogram of e-courses in different languages.

From the survey it could be concluded that most BME e-courses belong to the second cycle (Master of Science) of qualification, Figure 2.

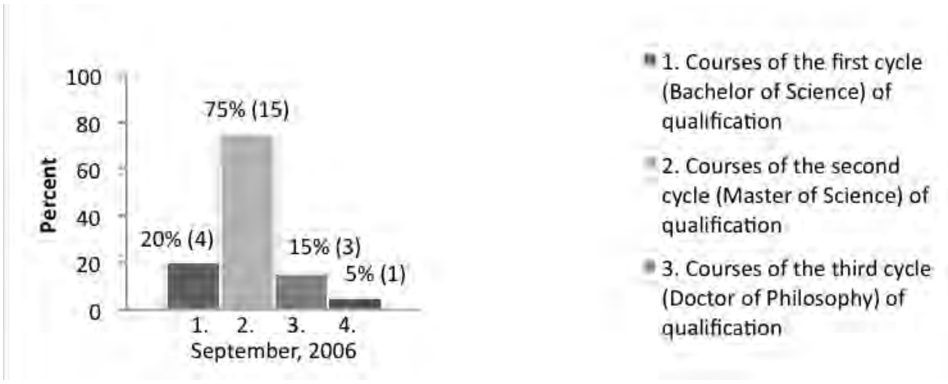


Figure 2. Distribution of e-courses displayed as the belonging to the cycle of qualification.

The most common e-course topics were Biomedical Instrumentation and Technology together with Imaging Systems and Image Processing. Figure 3.

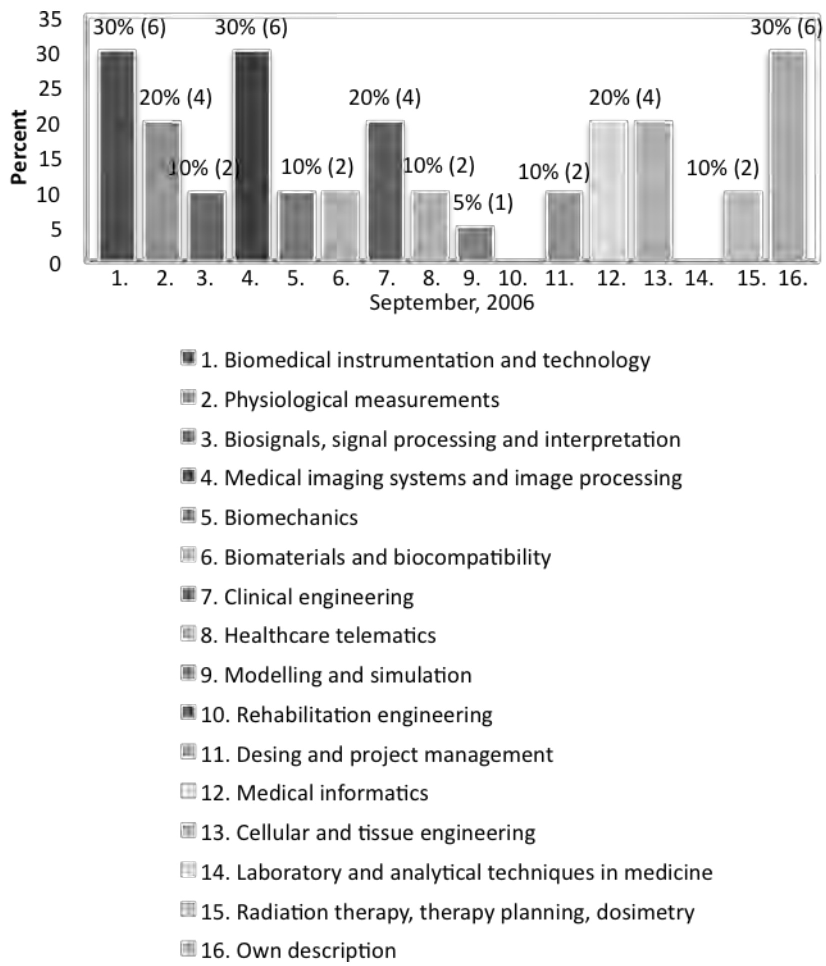


Figure 3. Distribution of e-course according to the topics defined by BIOMEDEA [19].

ECTS credits have been widely used to define workload of e-courses. Half of the recently reported e-courses award students with 5 ECTS credits. Several educational institutes reported courses having more than 60 ECTS credits. We have reason to believe that this indicates some kind of misinterpretation since such a workload would render full time studies of a year or more. The enrollment in the e-courses varies between 5 to 40 students, Figure 4.

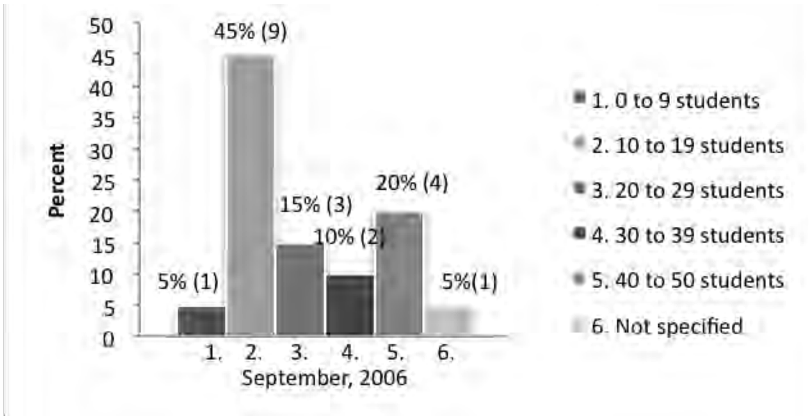


Figure 4. Histogram distribution of e-courses with the number of enrolled students.

The most important resources from people to machines belonging to the e-courses were: tutors, course literature, PCs / Internet, laboratory works, student work, e-platform and demonstrations.

The duration of the e-courses lasted between 10 to 15 weeks (~57 percent), one being a part-time course (24 weeks) and the remaining being short courses, 4 to 7 weeks long, until September, 2006. Most of the courses (~57 percent) were available during the fall semester, while only one of the courses were running independently of time. The majority of the e-courses were delivered each academic year (82 percent), until January, 2010.

3.3 Internal and external quality assurance

Several different measures have been proposed for use as indicators of quality assurance in BME e-courses. The most common measures until September, 2006 were:

1. Feedback by students.
2. Internal quality controls at a university level.
3. Peer review and internal work at an institutional level

This priority list changed between the surveys and now the most common measures until January, 2010 were:

1. Internal quality controls at a university level.
2. Feedback by students.
3. External reviews.

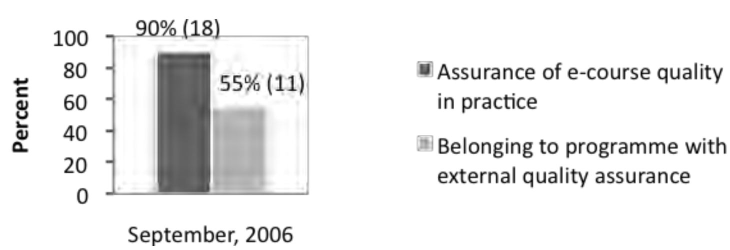


Figure 5. The distribution of e-courses according to measures taken for quality assurance.

The external quality assurance systems in use until September, 2006 were:

- at the national level, e.g., controls by external bodies or reviewers, use of field expertise in an educational context , assuring the quality of teaching or tutoring (for majority of e-courses),
- at the international associations, e.g., ENQA (for minority of e-course).

External quality assurance bodies in use until January, 2010 were mainly at the national level, e.g., as part of the Faculty of Medicine or national higher education quality agency.

Continuous measures were taken to assure a qualified and competent teaching staff that facilitates student learning. Until September, 2006 there measures were:

- participation in relevant seminars and standardization initiatives,
- visits to another universities,
- teachers with other education background.

Continuous measures until January, 2010 were:

- pedagogical training,
- seminars within teaching projects,
- survey and faculty control,
- mentorship programmes,
- students' evaluation,
- self and peer assessment.

3.4 Student mobility, lifelong learning and transparency

More than half of the e-courses have been publishing the learning outcomes. The trend to publish the students' assessment criteria has increased during the past years. The most frequent means of publishing course outcomes (goals) was WWW and course home pages. For several courses, the outcomes were delivered to the students directly, by means of handouts until September 2006. Up-to date impartial and objective information about the e-courses was published regularly (once a year) by minority of respondents in order to attract students to enroll in the courses.

Usually 5 to 30 students enrolled from other universities and among those about 5 to 10 students came from foreign universities. It was also reported that only several students had working experience in BME until September 2006 [24].

Communication between students, teachers and tutors within the e-courses was arranged in multimodal ways. Thus, the direct, face-to-face communication was preferred, Figure 6.

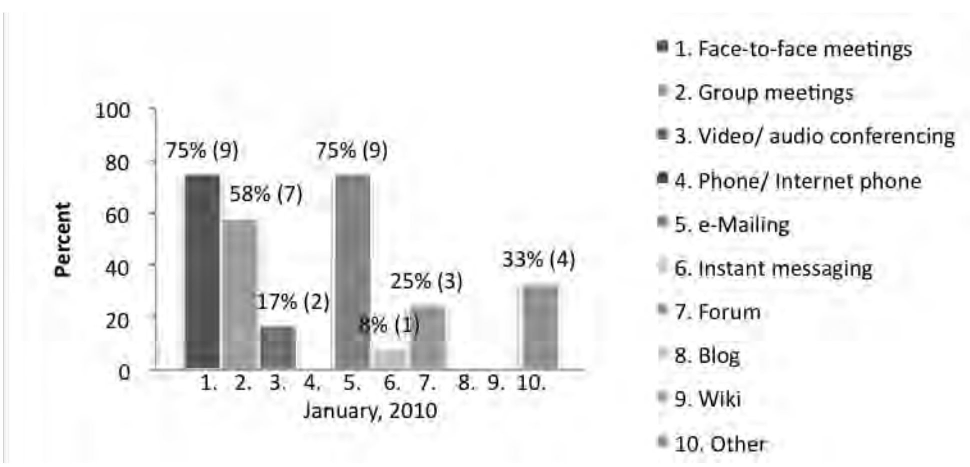


Figure 6. Histogram showing communication strategies between students, teachers and tutors in e-courses.

3.5 Application and recognition

More than half of the respondents informed that they have been using or plan to use, in their own teaching the material provided by EVICAB, Figure 7.

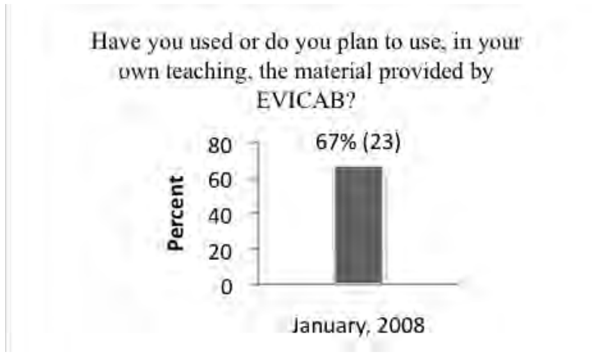


Figure 7. Usage of material provided by EVICAB. Number in parenthesis indicates the real number of persons / answers.

The responders stated that they would encourage their students to participate in virtual exchange studies, using EVICAB resources and recognize their learning outcomes, Figure 8.

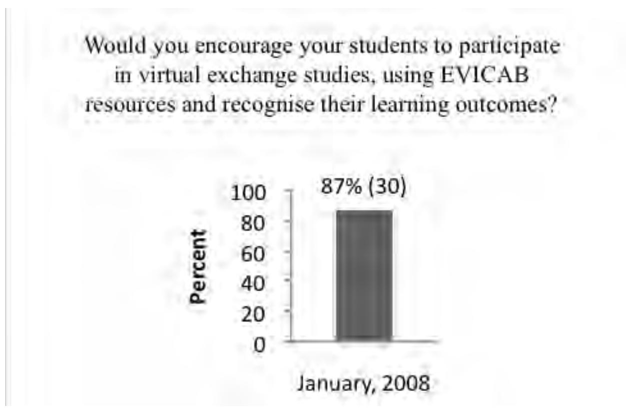


Figure 8. Percentage of course stake holders that would like to encourage students to participate in virtual exchange studies.

Recognition of learning can primarily be made through the accreditation of credit points and grading. Results of the survey showed that that educators prefer Erasmus exchange contracts when recognizing credit points and grades from other universities. Earlier, before January, 2008, educators considered also other options, e.g., own university agreement or bilateral university agreement, Figure 9.

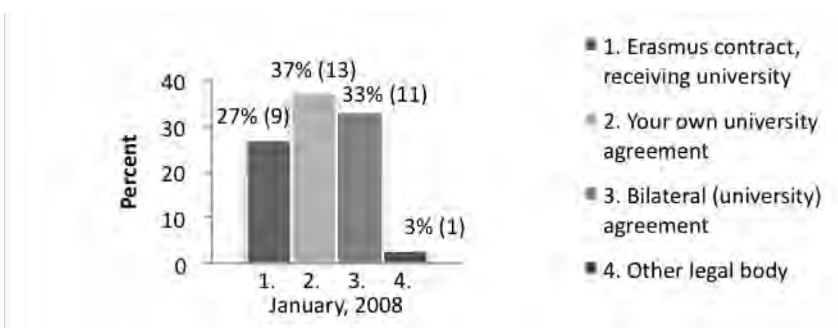


Figure 9. Histogram display of recognition procedures.

Majority of teachers indicated that they are or would be able to provide different specific educational resources to the virtual education, e.g., in EVICAB portal. Lecture materials including slides and animations are the most common resources. In addition, video lectures, textbooks, e-books and virtual laboratory works can be provided. The number of virtual laboratory works is quite low, although every teacher in engineering education understands how important they are for the learning process, Figure 10.

Figure 10. Percentage use of educational resources in e-courses.

3.6 Supplementary issues

The teachers and programme coordinators expressed interest in virtual education; almost 83 percent of responders stated that they would like to promote their e-course through virtual learning platforms, based on comparable and mutually recognized qualifications. The responders were also interested in the possibility to answer a follow-up questionnaire concerning the pedagogical issues and development of e-learning in BME.

4. Discussion and conclusions

The purpose of this report is, through three different but linked surveys, to present how e-learning has been developing and has been applied in BME education. The main findings of the study are following.

Practical issues

- BME e-courses have been developed and established during the investigation period. The predominant language for delivered e-courses are English and they belong to the second cycle (Master of Science) of qualification. Most of the e-courses are awarded with 5 ECTS credits and last from 1 to 3 months. Usually, in the range 5 to 40 students are enrolled in the e-courses.

Internal and external quality assurance

- The survey results showed that measures for quality assurance of e-courses, may have a large variation.
- The consequence is, there is no common system for quality assurance in BME e-learning. Therefore, the primary concern should be, not to develop new quality concepts, but to adapt already existing ones.

Student mobility, lifelong learning and transparency

- The number of students, enrolling in e-courses from other universities, has been increasing. This indicates that learning is becoming more mobile, i.e., not limited by a physical campus programme of only one educational center.
- The fact that students do not have to relocate in order to participate in e-courses creates new concept, i.e., “virtual mobility”.

- BME education centers provide information about e-courses content, their learning outcomes and assessment criteria. The transparency of e-courses can motivate more students to enroll.
- BME students do not have much working experience in the field. It may be assumed that students, who enroll in e-courses, require basic knowledge and information.
- There are different possibilities for communication between students and teachers in e-courses, e.g., forums, instant messaging or video / audio conferencing. Thus, teachers prefer face-to-face communication and group meetings.

Application and recognition

- Teachers have a lot of experience in working with virtual educational materials.
- The majority of teachers have developed or are able to provide lecture materials including slides and animations for virtual education.
- Teachers encourage students to participate in virtual exchange studies and recognize their learning outcomes.
- E-courses still support a teacher-centered approach, where knowledge is unidirectional, i.e., from teacher to students. Therefore, there is a great need for virtual laboratory work and exercises, where students could apply theoretical knowledge and develop practical skills.

Other issues

- Teachers have shown interest to further develop virtual education for BME and to promote e-courses via virtual platform based on comparable and mutually recognized qualifications.

Despite the obtained data, the presented report cannot reveal so accurate information due to limited amount of responses. Not all responders could be reached because of outdated email addresses or changed positions. The benefit of such survey would be that it allows getting reliable, not publicly available information from the key persons who are responsible for education by designing courses and / or curricula. In general, our surveys prove that teachers are interested in further developments and implementations of e-learning for BME education.

References

[1] T.R. Harris, J. Bransford, and S. Brophy, "Roles for learning sciences and learning technologies in biomedical engineering education: a review of recent advances," *Annual Review of Biomedical Engineering*, vol. 4, 2002, pp. 29-48.
[2] G. Fonseca, J. Destro-Filho, and V. Borges, "Online learning system for biomedical engineering," 2007.
[3] S. Tabakov, "e-Learning development in medical physics and engineering," *Biomedical Imaging and Intervention Journal*, 2008.
[4] H. Huy, N. Thuan, and V. Hai, "Building an elearning website for biomedical engineering education," *Proceedings of the 3rd International Conference on the Development of BME*, Vietnam: 2010.
[5] J. Bronzino, *Biomedical Engineering Handbook*, CRC Press LLC, 2000.
[6] M. LaPlaca, W. Newstetter, and A. Yoganathan, "Problem-based learning in biomedical engineering curricula," *Frontiers in Education Conference, 2001. 31st Annual*, 2001, pp. F3E-16-21 vol.2.
[7] Central Intelligence Agency, "The World Factbook," *The World Factbook*, May. 2010.
[8] E. Cloete, "Electronic education system model," *Computers & Education*, vol. 36, Feb. 2001, pp. 171-182.
[9] D. Keegan, *Foundations of distance education*, Routledge, 1994.
[10] T. Chan, C. Hue, C. Chou, and O.J.L. Tzeng, "Four spaces of network learning models," *Computers & Education*, vol. 37, Sep. 2001, pp. 141-161.
[11] J. Williams and M. Fardon, "Perpetual connectivity: lecture recordings and portable media players," *Proceedings ascilite Singapore 2007*, 2007.
[12] J. Duncan-Howell and K. Lee, "M-learning: finding a place for mobile technologies within tertiary educational settings," *Proceedings ascilite Singapore 2007*, 2007.
[13] Gwo-Jen Hwang, "Criteria and Strategies of Ubiquitous Learning," *Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006. IEEE International Conference*, 2006, pp. 72-77.

[14] A. Nagy, “The Impact of E-Learning,” *E-Content*, 2005, pp. 79-96.
[15] R. Carol, “E-learning adoptation in a campus university as a complex adaptive system: mapping lecturer strategies,” 2008.
[16] Benelux Bologna Secretariat, “Bologna Process. Towards the European higher education area,” 2009.
[17] ENQA Secretariat, “The European Association for Quality Assurance in Higher Education,” 2009.
[18] Education and Culture DG, *The EU contribution to the Bologna Process*, Belgium: 2009.
[19] BIOMEDEA Project, *Criteria for the accreditation of biomedical engineering programs in Europe*, Institute of Biomedical Engineering, University of Stuttgart, 2005.
[20] U. Ehlers, L. Goertz, B. Hildebrandt, and J. Pawlowski, *Quality in e-learning. Use and dissemination of quality approaches in European e-learning. A study by the European Quality Observatory*, 2005.
[21] J. Malmivuo, “EVICAB,” *www.evicab.eu*.
[22] J. Malmivuo, J.J. Nousiainen, and A. Kybartaite, “Biomedical Engineering Program on the Internet for Worldwide Use,” *14th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics*, 2008, pp. 5-7.
[23] BIOMEDEA Project, *Biomedical engineering education in Europe - status reports,* Germany: Institute of Biomedical Engineering, University of Stuttgart, 2005.
[24] E.G. Salerud, H. Petersson, and M. Ilias, *European biomedical engineering e-learning. Survey report of existing and planned BME distance courses in Europe.*, Linköping University: Institute of Technology, 2006.
[25] “Webropol,” 2009.