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IMPACT OF MODERN EDUCATIONAL TECHNOLOGIES ON LEARNING OUTCOMES: APPLICATION FOR E-LEARNING IN BIOMEDICAL ENGINEERING

PhD Thesis

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ABSTRACT

The arrival of new technology is often followed by efforts to apply it for educational purposes, e.g., audio and video records, CD-ROM and DVDs, personal computers (PCs), iPods, Internet and Web 2.0 applications, e.g., wikis, blogs and podcasts - all that have been followed by educators taking up each of these tools and adapting them for educational purposes.

The research work for this thesis has been done in order to develop a virtual campus for Biomedical Engineering (BME). The work has been initialized in the EVICAB project, European Virtual Campus for Biomedical Engineering (January, 2006 – December, 2007). The projects had an aim to develop, build up and evaluate 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 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 Presentation or PDF document were synchronized in one application, in Flash format. Video file converting software was used to obtain MP3, MPEG-4 and 3GP file formats for audio, video players, and mobile phones. It became possible to access files with open software, i.e., iTunes and QuickTime player, and then upload them to personal gadgets. WordPress blog tool and publishing platform was implemented as asynchronous communication system. Virtual users have possibility to leave their comments, messages and suggestions. Rating system was added so that the users could evaluate each lecture, which consists of several video records. Hypertext Markup (HTM) language was applied to present all materials as a web portal. Web code maybe used as an open source; everybody may contribute to its development by downloading and editing it. A layout and color schemes have been selected so that accessibility and usability of the environment is as easy and user-friendly as possible.

The above mentioned materials and methods have been tested when implementing 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 virtual learning environment. A questionnaire was developed to collect feedbacks from 66 students, who participated in the course, for preliminary evaluation of implemented methods. The questionnaire included 20 closed- and opened-ended questions. Students had possibility to express opinions by selecting one or more answers from multiple-choice questions and commenting in own words. Several answers had grading system – Likert scale from 1 to 5; where 1 was for not useful, 5 – very useful.

Analysis of log-ins to the virtual campus has been done in order to get information when, from where and how (e.g., by PC, downloaded for iPod or media phone) users accessed the portal. This information helps to improve the content and also proves that the virtual campus has been accessible. Virtual users assessed learning materials every weekday; average number of visits has been more than 40 per day, from all over the world. Video lectures for PCs were accessed the most, then video lectures for iPods and video lectures for media phones. Most of the users have been accessing virtual materials with Firefox browsers using Windows operating machines. This information is important for further development as not every browser on every operating system is able to correctly decode video files.

In order to make the estimate how e-learning has been developing so far (during the years 2006-2009) among BME education offering centers in Europe and to anticipate its development in the near future three questionnaires were administered and data about BME e-courses has been obtained. It is anticipated that this information could give motivation to plan future e-learning for BME and be useful in defining educational plans and goals.

After familiarizing with teaching and learning theories, and similar experiences in BME, it was possible to compare own experience and make improvements when developing the virtual campus. Constructivism theory was followed and it was important to make the virtual campus acceptable for 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 learning and teaching independent of time, place and pace. 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, free, modern technology based virtual campus. Thus new technical boundaries appeared. They have been diminished by considerate technology analysis and design. This research supports the idea that the main focus is in the learning content and educational technology serves to sustain it. BME educators are in a position to design and implement new learning systems that can take advantage of advances in learning science, learning technology, and reform in engineering education (Harris et al, 2002).

ACKNOWLEDGEMENTS

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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*, - conditionally accepted after minor revision, 2010.

IV. Kybartaite, A., and Malmivuo, J. Learning objects for the virtual campus of biomedical engineering. *IEEE Multidisciplinary Engineering Education Magazine (MEEM)*, - submitted, 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, WC 2009*, Munich, Germany, 7.-12.9.2009, vol. 25, 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, WC 2009, 7.-12.9.2009, Munich, Germany.

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, vol. 20, 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. *eLearning Baltics, eLBa Conference*, - accepted extended abstract, 2010.

AUTHOR'S CONTRIBUTION

The research work was divided into four different approaches, i.e., theoretical, practical, evaluative and developmental.

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

Practical approach deals with software and hardware implementations and virtual campus development. Manuscript III presents an overview of technologies and methods used to create the virtual campus. Manuscript IV presents learning objects of the virtual campus. Publication V analyses importance of video in education and presents a method to develop 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 BME discipline, explains organizational issues within EVICAB, analyses benefits for students, teachers and educational institutions, evaluates possibility to transfer learning materials to portable devices, e.g., iPods, media phones. Publication VIII describes practice for creating, editing, and distributing video. Also the publication is an example of collaborative work. Publication IX considers advantages and disadvantages of video lectures, theoretical background behind video lectures, analyses similar examples of video lectures, presents initial attempts to develop and evaluate video lectures. The author contributed to the development of virtual campus and particularly video lectures, wrote Manuscripts III and IV, and Publications V and IX.

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

Developmental approach aims to analyze past experiences and anticipate future trend of e-learning in BME. Publication XI analyzes how e-learning has been developing so far in BME field in Europe. Therefore three questionnaires have been prepared and sent to BME education offering centers. It was anticipated that collected data could give motivation to plan future e-learning for BME and be useful in defining educational plans and goals. The author contributed to the development of the 2nd and 3rd questionnaire, analyzed data and wrote the extended abstract.

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 e-Learning and e-Teaching Practices. EVICAB project report, available at *www.evicab.eu*, 2006.

The following supplementary publications, XIV-XV, are related to Biomedical Engineering discipline, but are not included to 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. *Biomedizinische Technik, in press*, 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-
MAC	Macintosh
MB	Mega bytes
MP	Medical physics
MP3	MPEG-1 audio layer 3
MP4	MPEG-4 video, file format
MPEG	Moving picture expert group
Moodle	Modular object oriented dynamic learning environment
MySQL	My structured query language
MSc	Master of Science, second cycle of educational qualification
PC	Personal computer
PDF	Portable document format
PHP	Hypertext preprocessor
PhD	Doctorate of Philosophy, third cycle of educational qualification
PPT	Microsoft PowerPoint
WMV	Windows media video
3GP	Multimedia container format defined by the Third Generation Partnership Project.

1. INTRODUCTION

Biomedical Engineering (BME) is a multidisciplinary and one of the fastest growing fields of science with 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 members of its educational process (Harris et al. 2002), i.e., for:

- Students, who are fostered to apply classical engineering concepts in profoundly new ways relating them to living elements (Schreuders & Johnson 1999). These students seek university degree or just in time information, are international, visiting or exchange students, ne(x)t generation students, who mainly study outside the classroom, with work or family commitments, or who due to health problems or disabilities are not able to attend classroom lectures.
- Educators and faculties, that are demanded to keep up with all the advances in the related fields, to develop new learning curriculum, environments and reasoning strategies foreseeing needs of prospective employers of graduates (Benkeser 2006), (Newstetter & A. Yoganathan 2002), (Harris & Brophy 2005).

- Employers of graduates, who request a wide range of capacities (Benkeser 2006), (Linsenmeier 2003).

Educational programmes in the field of BME had their origins in the 1950s as several formalized training programmes were created (Benkeser 2006). By the year 2005, more than 200 universities of applied science, polytechnic schools, academies and other institutions in Europe offered educational programmes in BME at all academic levels (BIOMEDEA 2005). Thus, still many of educational programmes in the field of BME are under the process of development (Nagel 2007). In general, engineering education has seen a massive transformation over the last few decades (Laurillar 2001), (Joseph Lee et al. 2001). 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 (Magennis & Farrell 2005), (Lechner 2001). Teaching and learning has moved towards more active (Prince 2004), student-centered (Lechner 2001), problem-based (LaPlaca et al. 2001), challenge-based (Harris & Brophy 2005), inquiry-based (Rocard et al. 2007), cooperative (DeZure 2000) and self-directed learning (Song & 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 & Jr 1989), CD-ROMs and DVDs (Eaton et al. 2008), personal computers (PCs) (C. C. Kulik & J. A. Kulik 1991), iPods (Palmer & Devitt 2007), Internet and Web 2.0 applications, i.e., wikis, blogs, podcasts (Boulos et al. 2006) have been adapted for educational purposes. Evolution of educational technology has lead to electronic (Cloete 2001), distance (Keegan 1994), network (Chan et al. 2001), portable (Williams & Fardon 2007), mobile (Duncan-Howell & Kar-Tin Lee 2007), ubiquitous education (Gwo-Jen Hwang 2006), educational semantic web (Aroyo & Dicheva 2004), and intelligent education models (Guangzou et al. 2006), etc. Thus, nowadays 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 prove significance of educational theories, technologies and models through an open, free of charge, modern technology-based and high quality teaching and learning environment. An example of such environment is European Virtual Campus for Biomedical Engineering, EVICAB. It commenced on January 2006 as the two years 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 follow the Bologna process (Benelux Bologna Secretariat 2009), i.e.:

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

The ideas and experiences of the project were disseminated in the international conferences (Malmivuo et al. 2008) and raised wide interest in future possibilities and applications of e-learning.

All that impelled to continue the study after the project time was over concentrating on the topic ‘Impact of Modern Educational Technologies on Learning Outcomes: Application for e-Learning in Biomedical Engineering. The purpose of the study was first to make theoretical evaluation of technology enhanced education (theoretical approach), then develop new portal for e-learning (practical approach), after that experimentally study how students accept e-learning (evaluative approach), and estimate 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 general requirements for a virtual campus, and half experimental, aiming to define individual processes specific for the virtual campus for BME. The following facts 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 institutes in BME are able to develop and provide up-to-date learning materials for students.
- Guidelines for harmonization, accreditation and improving quality assurance has been under the process of establishment by BIOMEDEA project.
- Internet and modern technologies are more and more used in the higher education.
- Educational theories can provide foundation for Internet education, e-learning or virtual education.

- Globalization encourages students and educators to mobility. Virtual mobility is relatively a 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 that.

2.2 TASKS OF THE STUDY

Finding answers to the following questions, implementing and testing feasible ones were the primary tasks of the study. That was possible only when developing and implementing the virtual campus for BME.

1. What cycle of qualification of BME education is needed for virtual education?
2. What learning resources can be included in virtual education?
3. What technologies and techniques can be applied and utilized in virtual education?
4. What technical resources are needed for virtual education?
5. How / what laboratory works could be implemented in virtual education?
6. How is it possible to provide instructions and tutoring in virtual education?
7. How to arrange students' examinations and provide possibility to test own knowledge?
8. How institutes can collaborate in order to get help and information?
9. What language could/ should be used in virtual education?
10. How BME students appreciate virtual education?
11. What is the effect of virtual campus on international and cultural level?

These answers can help in the future development of e-learning for any discipline.

2.3 OBJECTIVES OF THE STUDY

The research work concentrates on four main objectives leading to conclusions:

1. Reviewing various learning technologies and theories.
2. Develop the virtual campus for BME, which can be easily adapted to other disciplines.

3. Evaluating how students accept e-learning based on experimental methods.
4. Analyzing development process of e-learning.

The first objective concerns learning theories supporting Internet education, e-learning or virtual education. The purpose is to theoretically define how to make the virtual campus pedagogically reasonable, acceptable by students, high-quality and modern-technology based. Literature review was done in order to define best-practices.

The second objective deals with the development of virtual campus for BME and implementation of e-learning objects 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 concentrates on the evaluation how technologies and methods for the virtual campus are accepted by students and educators. In order to collect quantitative and qualitative data for evaluation, questionnaire for students was prepared and data from website statistics' counter was analyzed.

The fourth objective concerns the development process of e-learning in general. International survey has been sent to BME education offering centers and opinions from course developers and teachers were obtained.

3. REVIEW OF THE LITERATURE AND THEORETICAL BACKGROUND

3.1 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 individual to become a problem solver, critical and creative thinker. Learning also helps to create within an individual awareness of oneself and environment in which he or she exists. Teaching has an aim to make learning possible. While the aim of teaching is simple, activity of teaching is complex. There are many theories, which aim to support 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 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 (Kaur et al. 2005). Atkinson-Shiffrin Model (1968) proposes 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 supervisory system and controls the flow of information from and to its slave systems; the phonological loop, visual-spatial sketchpad, and 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) promotes less reliance on professor's lectures while simultaneously creating more self-reliance among students (Mayer 2005). Mayer's Theory of Active Learning (SOI) states that a promise of multimedia learning is that teachers can utilize the power of visual and verbal forms of expression in the service of promoting 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). Constructivims Theory states that: (1) knowledge is constructed, not transmitted, (2) prior knowledge impacts the learning process, (3) initial understanding is local, not global and (4) building useful knowledge structures requires effortful and purposeful activity (Moore 2000). Cognitivism Theory informs that knowledge can be seen as schema or symbolic mental constructions, while Theory of Behaviorism proves that learning is nothing more than the acquisition of new behavior (Moore 2000).

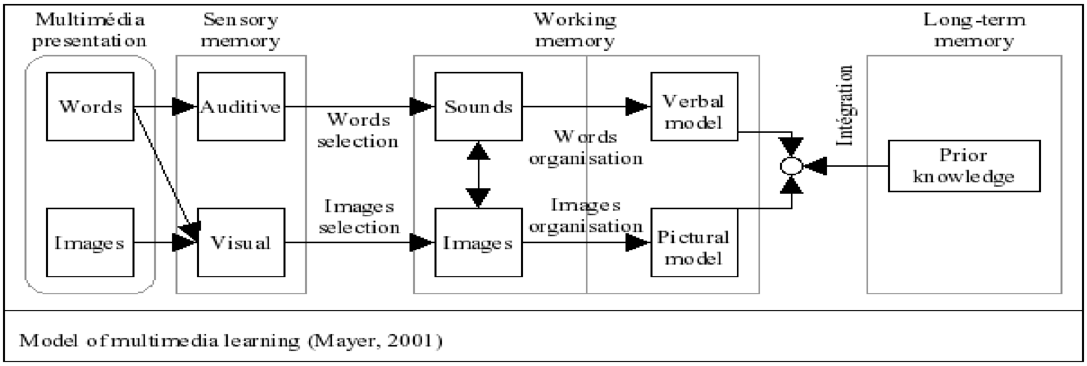

Figure 1. Mayer's selecting-organizing-integrating (SOI) theory of active learning. Adopted from (Mayer 2005).

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 applications in education.

3.1.1 Learning process according to human brain

According to neuroscience approach the nervous system and the brain are the physical foundation of the human learning process (Funderstanding n.d.). Then learning is the result of structural modifications within the brain when integrating all information perceived and processed, Figure 2. This means that the brain is continually changing and developing all our life. At the same time our skills, knowledge, experience is also developing. The definition that neuroscientists use for learning links to 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 (Funderstanding n.d.), i.e., left side is responsible for logical, sequential, rational, analytical, objective thinking, whereas, 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 learning processes".

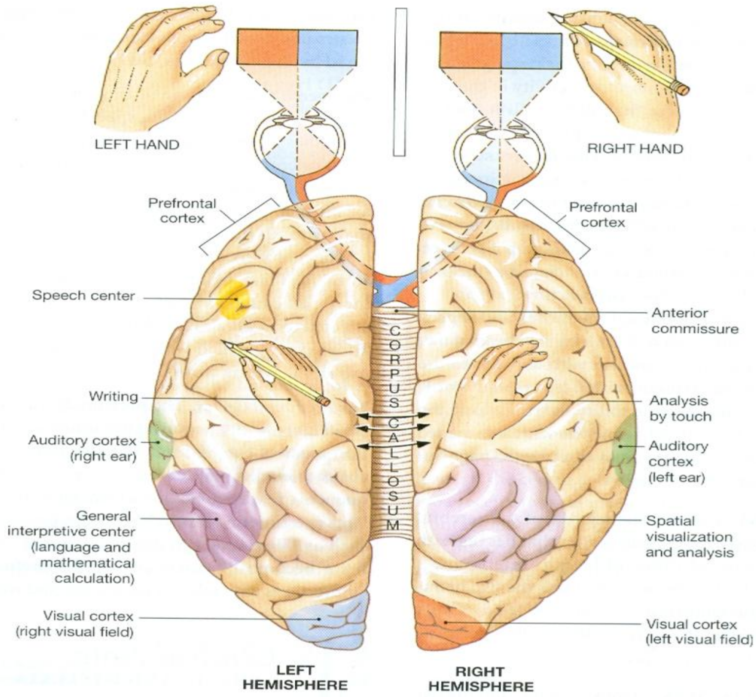

Figure 2. Hemispheric lateralization. Some differences between the left and right cerebral hemispheres. Adopted from (Martini & Bartholomew 2007)

3.2 EDUCATIONAL TECHNOLOGY

A concept of educational technology is a fundamental theoretical grounding for research and practice in teaching and learning. The field of educational technology is relatively new and has been struggling in defining its foundations (Luppicini 2005). According to Association for Educational Communications 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 systematic engineering knowledge of how to design artifacts. Social science scholars view technology as a process for material construction based on 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 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. It is possible to illustrate educational technology as a system, Figure 3.

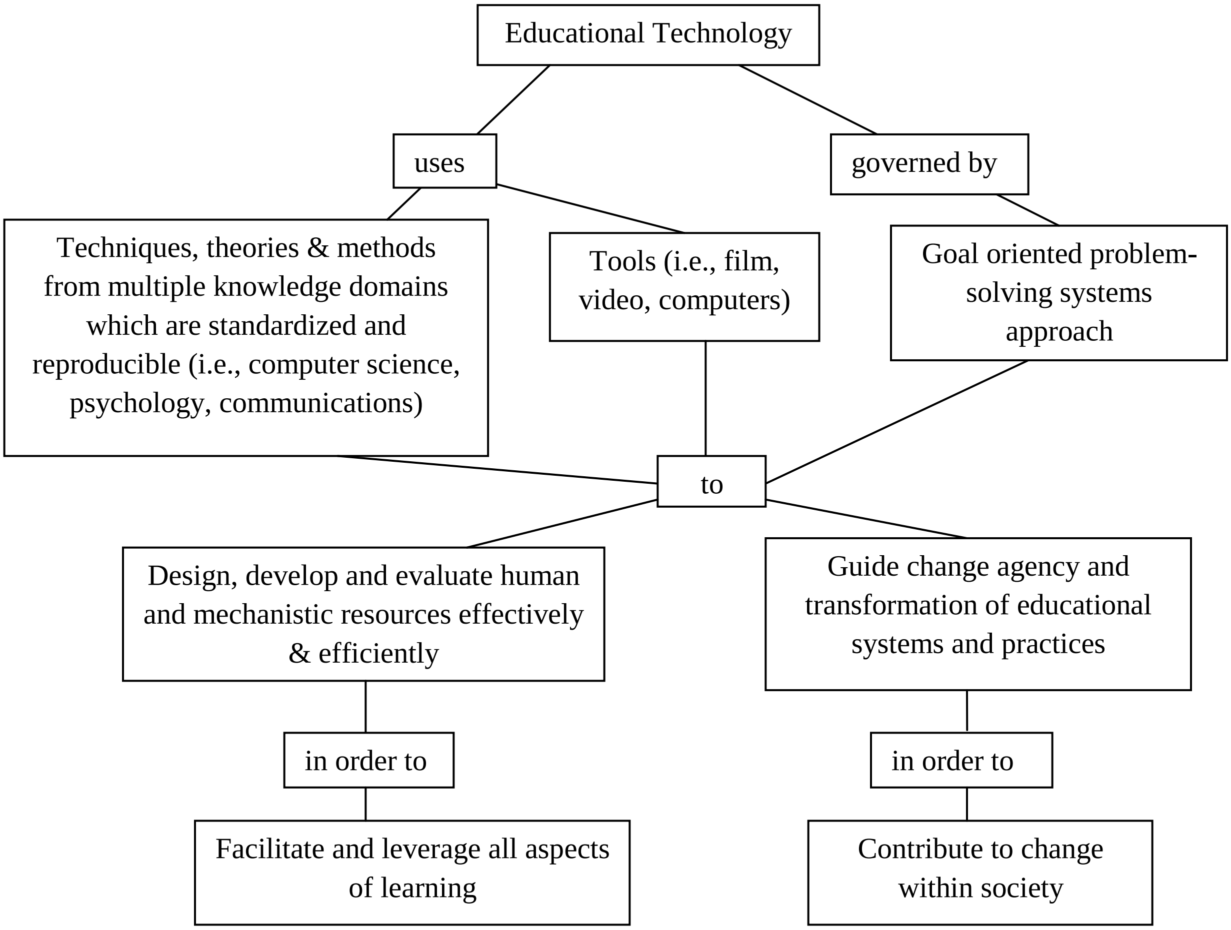

Figure 3. A systems definition of educational technology in society. Adopted from (Luppicini 2005).

When writing this thesis, the main approach to the educational technology was considering it as a tool. The history of educational technology as a tool is marked with significant innovations. The list of innovations includes various hardware, e.g., portable storage devices, portable CD, DVD players, calculators, notebook PCs, handheld PCs, pocket computers, personal digital assistants (PDAs), mp3 players, iPods, digital video cameras, etc. In general, arrival of any new technology (i.e., software and hardware), especially in entertainment field, is often transformed for educational purposes and universities are increasingly promoting the use of them in a class (Palmer & Devitt 2007). Furthermore, diffusion of WWW, Internet and other media, e.g., radio, TV with evolving social software and communication applications (e.g., Skype, Facebook, messenger and various forums, blogs, wikis) enabled people to communicate and get information unbelievably in the past. A wide range of terms appeared describing possible ways 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 instructions, 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. The term 'virtual' means 'having most properties, the appearance, essence, or effect, of something without being that thing' (business dictionary). 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).

3.2.1 Instructional technology

Quite often educational technology and instructional technology is considered as synonyms. Thus according to AECT (1994) instructional technology is the theory and practice of design, development, utilization, management, and evaluation of process 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 when lecturer stands and talks in front of a room and a large group of people listen try to understand and write at the same time. Lecture originated from the days when printed material and copies of text were not widely available. Nowadays technologies provide possibility to copy, print, scan, digitally save, etc., materials and text. But still today traditional classroom lecturing is one of the most common teaching methods. Traditional lectures have several advantages:

- lectures provide possibility 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.

Whereas, disadvantages include facts that:

- usually lectures have too many people,
- different people catch onto different information at different rates,
- usually lectures are one-way delivery information
- receiving information is difficult in a real time because it is necessary to keep exact pace with the information arriving,
- 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 the traditional classroom learning. It has also become one of the fastest moving trends in education (Zhang et al. 2004).
Advantages of e-learning include:

- self paced, flexible, accessible, convenient learning process,
- savings on cost and time,
- focused on learning through more active participation,
- easier content management, simpler data management, ease of update,
- possibility of linking the content with other learning resources,
- integrated assessment and testing facilities,
- variety of measuring methods of the learning success.

Disadvantages include facts that:

- e-learning cannot happen without supporting technologies,
- reliability of technologies, tools is not always sufficient,
- there is a distance between teacher and peers.

3.2.2 E-learning

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) technologies,
b) content and
c) instructional methods or process.

According Zhang et. al., (2004) e-learning can be defined as technology-based learning in which learning materials are delivered electronically to remote learners via a computer networks. Clark (Connolly 2009, chap.8) describes e-learning as a content and instructional methods delivered on a computer (whether on CD-ROM, the Internet, or an intranet), and designed to build knowledge and skills related to individual or organizational goals. 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 been developed at an unprecedented speed over the last 20 years. Internet started as a new open system of information sharing between some thousand of scientists and evolved to a worldwide force of economic growth for billions of people. Due to the Internet’s open protocols anyone can access useful information, create and share knowledge, instantly message, make phone calls, etc. Thus experts in the field claim that still not all potential possibilities of applications and services support have 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 faster speed (Golden et al. 2007). According to the report (EU Commission 2010) the Internet access and broadband Internet connections are growing with the years. Broadband Internet access is defined as an access assuring an always-on service with speeds in excess of 144 kbps. This speed is measured in download terms. The term broadband commonly refers to high-speed Internet access, i.e., data transmission speeds exceeding 200 kilobits per second (Kbps), 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 is of kilobits, music five is of megabits, and a film is of several gigabits. Generally offered broadband access 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), mobile which might be called as next generation access (NGA) technologies (Parliamentary Office of Science and Technology 2008).

3.2.4 Virtual Campus

The Internet and especially World Wide Web (WWW) was one of the main reasons for 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, virtual campus can be defined as an environment that uses a metaphor of university (Fominykh et al. 2008). Usually virtual campus is an open system for the design, deployment and evaluation of reusable learning materials. Virtual campus is also often used to describe international cooperation among universities from several different countries (Schreurs et al. 2009).

3.3 EVALUATION of EDUCATION

3.3.1 Questionnaires and surveys

Students' feedbacks have been recognized as one of the most important considerations when assessing teaching (Holmes & Brown 2000). This type of assessment is most often performed at the end of the course and frequently is linked to future improvement decisions (Caulfield 2007). Constructively used feedback data can be beneficial for students through improved teaching and learning environment. Also may provide information for students when selecting course units or teachers. Administrators may benefit through more accurate representation of students judgments in the decision making process (Aleamoni 1999). Students' feedbacks are usually obtained by means of formal questionnaires. Other methods maybe useful as well, e.g., casual comments made inside or outside the classroom, meetings of staff-student committees, students representation of institutional bodies. Thus, questionnaires have two advantages: 1) provide opportunity to obtain feedbacks from the entire population of students, and 2) allow documenting experiences of the student population in more or less systematic way (Richardson 2005). The process of obtaining feedbacks 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. Just for that reason it may not always be regarded as a serious matter by those involved (Richardson 2005). Students' feedbacks collected by means of questionnaire provide information describing students characteristics and their distribution. Such study is known as descriptive survey and usually is concerned what the distribution is but not why observed distribution exists There are two major types of survey, i.e., cross-sectional and longitudinal. It is necessary to define an objective of research then it is easier to define type of survey. The objectives should be sufficiently interesting and important enough to motivate individuals to respond. There are different means to collect data in a survey, e.g., 1) by directly administering survey, 2) by mail, 3) by telephone (Internet-phone), 4) by interview, 5) by e-mail, 6) by web form, etc. Each of these means have advantages and disadvantages. The interaction mode and technological mode influence the nature of survey's questions and processes used to answer them. The collected data must 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 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, activities and actors can be defined. That is known as visitors' tracking (Barrett 2009), (Opentraker.net 2009). Technically, a visitor is the browser of a person who accepts a 'cookie'. By this definition, a visitor is a human being and his / her actions are 'human events' because only human use browsers to navigate the Internet. If a 'cookie' is not accepted then IP number can be used to track visitors. One visitor can make multiple visits to the site. A returning visitor is a visitor who visits a site with a 24 hours period in between. Usually website statistic systems allow getting information about hits, files, sites, visits, pages or Kbytes. Hits represent the total number of requests made to the server during the 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 repeated visitors, as the greater the difference between the two, the more people are requesting pages they already have 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. As long as the same site keeps making requests within a given timeout period, they will all be considered part of the same visit. If the site makes a request to the server, and the length of time since the last request is greater than the specified timeout period (default is 30 minutes), a new visit is started and counted, and the sequence repeats. 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 (as graphics and audio clips). A Kbyte (KB) is 1024 bytes (1 Kilobyte). It is used to show the amount of data that was transferred between the server and the remote machine, based on the data found in 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 under the process of development in Europe. For example, Bologna Process (Benelux Bologna Secretariat 2009) introduces three-cycle system and invites to consider how to make pedagogy more student-centered and given study adequately addressing needs of graduates. European Association for Quality Assurance in Higher Education (ENQA) (ENQA Secretariat 2009) provides Standards and Guidelines for Quality Assurance for the Higher Education. ERASMUS programme (Education and Culture DG 2009) has brought mobility to a wide range of students from different countries and backgrounds. Widely used ECTS, learner-centered system for credit accumulation and transfer¸ allows seeking recognition for what students have learned at home, abroad, in formal education, through self-study or through work experience (Education and Culture DG 2009). BIOMEDEA suggests 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, 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 (Nkuma-Udah et al. 2009), (Rae 2009), Australia (Mukhtar et al. 2009), Asia and Oceania (Suh 2009), (Krisanachinda et al. 2009), (Khambete 2009), (Mochimaru et al. 2009), (Shah & Hamid 2009), (Weng et al. 2009) Middle East countries (Duhaini 2009). The main problems that most of BME educators face are:

- lack of resources with respect to both qualified teachers and equipments which are at the disposal for teaching,
- quality assurance procedures to improve quality of academic education, accreditation process,
- standardized guidelines, and
- 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. Theoretical approach is considered in Chapter 3. Practical, evaluative and developmental approaches are considered in Chapter 4. Subchapter 4.1 presents the methods to develop virtual campus. Subchapter 4.2 presents study about the evaluation of the virtual campus based on students' feedback and web log-ins statistics. Subchapter 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 applying the virtual campus and its contents. Software tools involve 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), files' converting software (e.g., Movavi) and software for virtual communication (e.g., blog WordPress). Hardware tools involve computers and laptops, operating systems (e.g., Windows, MacOS), portable video and audio players (e.g., iPods, MP3 players) and media phones. These tools were used when developing the virtual campus.

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

(c)

(a) **(b)**

Figure 4. An example of presentation slide (in camrec format, 88,3 MB, 92 688 384 bytes) (a), video (Windows Media (TM) Video File, duration over 16 min, bitrates 521 kbps, dimensions 240x180, size 86,2 MB) (b) and audio data, (c) used for developing video lecture.

In order to include original presentation slides or document, screen capturing technology was used. It recorded computer's desktop activity. This required installing additional software to the computer. Camtasia Studio by TechSmith Corporation was selected. Screen captures were saved in .CAMREC files. Due to technical limitations sometimes it was not possible to capture the screen and save it. In that case .PPT or .PDF documents were converted to graphic file formats, e.g., JPEG. Recordings were stored to digital video format (DV) tapes and at the same time or later transferred to digital .AVI or .WMV file format using basic video creating and editing software, e.g., Windows Movie Maker. After initial editing, we applied Camtasia Studio software 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. Also file size becomes too large. The markers for tracking certain slides were placed on a time line. 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. We selected a very common .FLV file format for video lectures. All the files were placed on the server so that lectures are accessible via the Internet. The minimum bandwidth is 350 kilobits per second (Kb/s), thus recommended is 1 Mb/s in order to watch lectures without buffering pauses.

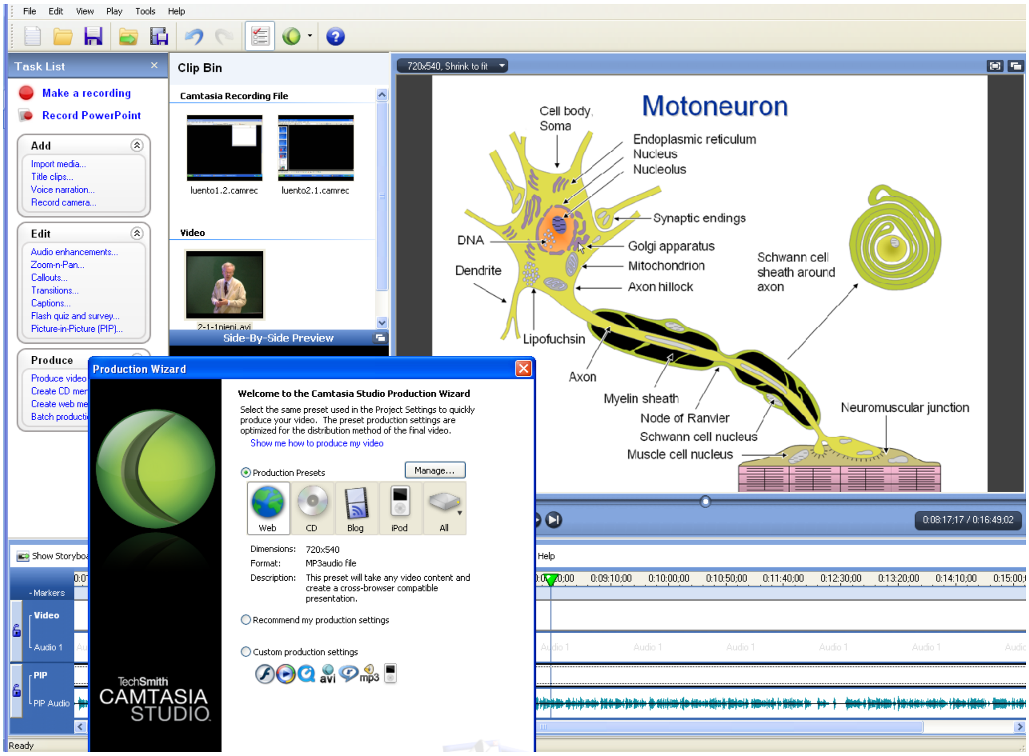

Figure 5. Editing window of a video lecture using Camtasia Studio software.

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

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 greater), which supports and runs a widely used, general-purpose PHP scripting language (version 4.3 or greater).

HTM was applied to present all materials in a website. Website code can be used as an open source; anybody can contribute to its development. Layout and color schemes have been selected so that accessibility and usability of the learning environment 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. Website has been optimized for the MozillaFirefox browser.

4.2 EVALUATIVE APPROACH

4.2.1 Questionnaire for students

When evaluating the virtual campus, 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. 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 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. Students' feedback was obtained by mean of questionnaire. Questions were closed- and opened-ended; students had possibility to express opinions by 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). The development of questionnaire involved 4 phases.

- Phase 1: A pilot version of the questionnaire with 12 questions and 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 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

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

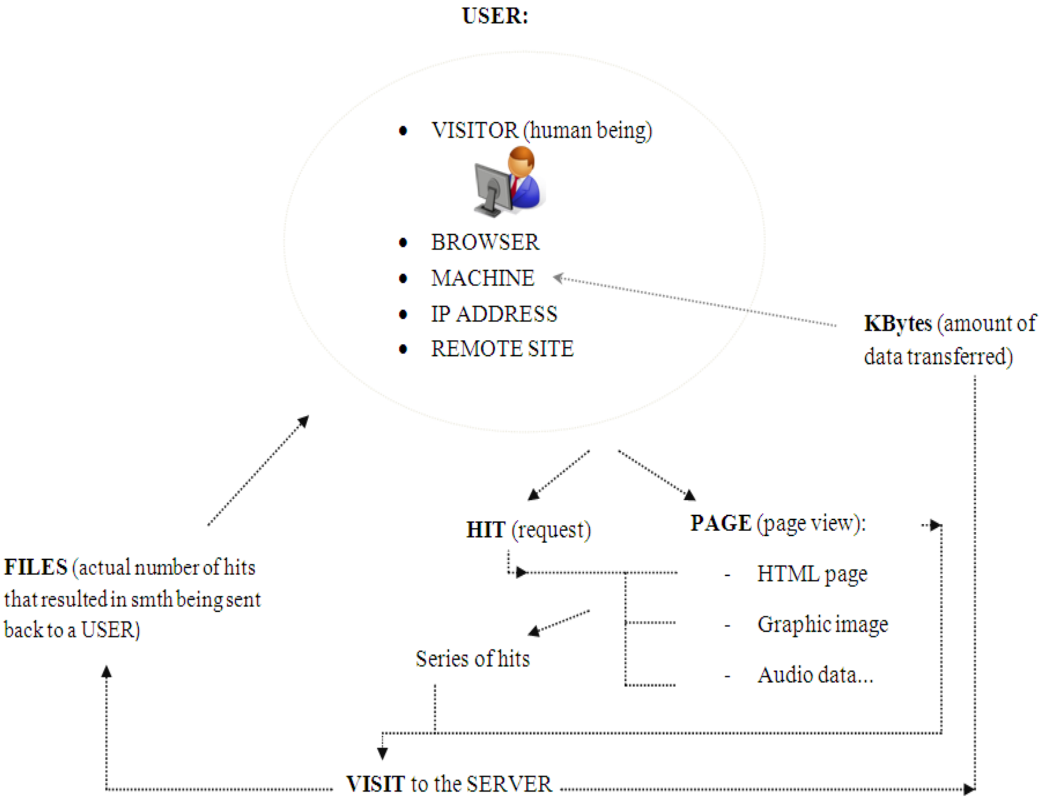

Figure 6. The generalized principle of web log-ins counting system.

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: questionnaire about existing and planned BME distance courses in two versions, an extended version that was answered by EVICAB members included 23 questions, and shorter one for other BME educational centers included 16 questions, was prepared by and sent out to a total of 263 persons, September, 2006. The survey was structured to sections:
    - practical issues (information about e.g., course duration, workload, operative language, topic and cycle according 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 used or planned to use EVICAB material, recognition and educational resources was prepared and sent out to the same respondents, January, 2008.
- Survey 3: 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 same respondents, December, 2009.

5. RESULTS

5.1 PRACTICAL PART

5.1.1 Virtual Campus

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

All courses within the campus provide general information for students and have e-books or suggest information and links about related books. All courses provide video lectures (altogether there are 247 video lectures). Several courses (25%) provide audio lectures (altogether there are 85 audio lectures). Majority of the courses (75%) include iPod lectures (altogether there are 162 iPod lectures). About 25% of all courses provide phone lectures (altogether there are 103 phone lectures). Several courses (25%) include lecture slides or notes. About 50% of all courses have exercises. All courses can be finalized as Internet exam, thus only 1 course has been practiced so far.

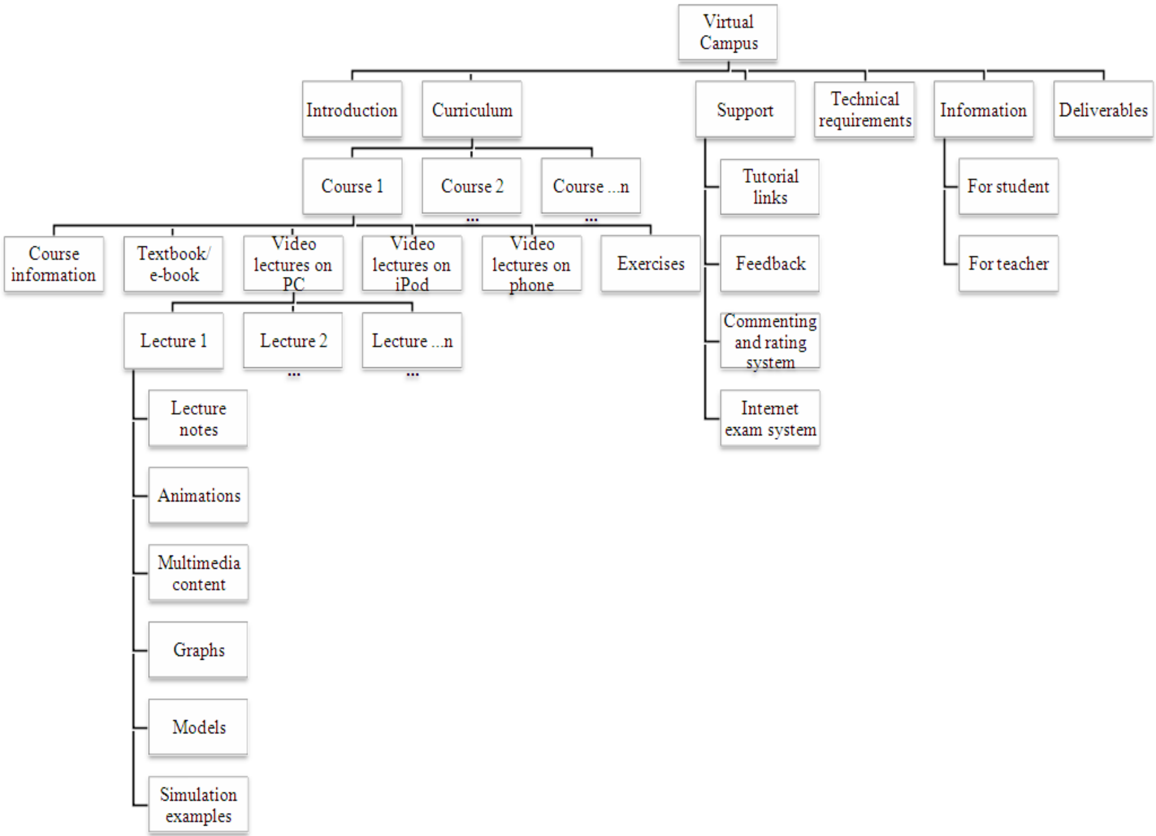

Figure 7. Generalized structure of the virtual campus.

5.1.2 Learning objects in Virtual Campus

Learning objects were developed and implemented in the virtual campus. The properties of learning objects are discussed in Manuscript II. E-learning consists of interaction of number of components, i.e., courses, assessments, teaching materials, study materials etc. These components have different characteristics; therefore they were grouped them into 5 levels. Grouped components are illustrated in Figure 8. It has been considered how these levels correspond with tradition learning.

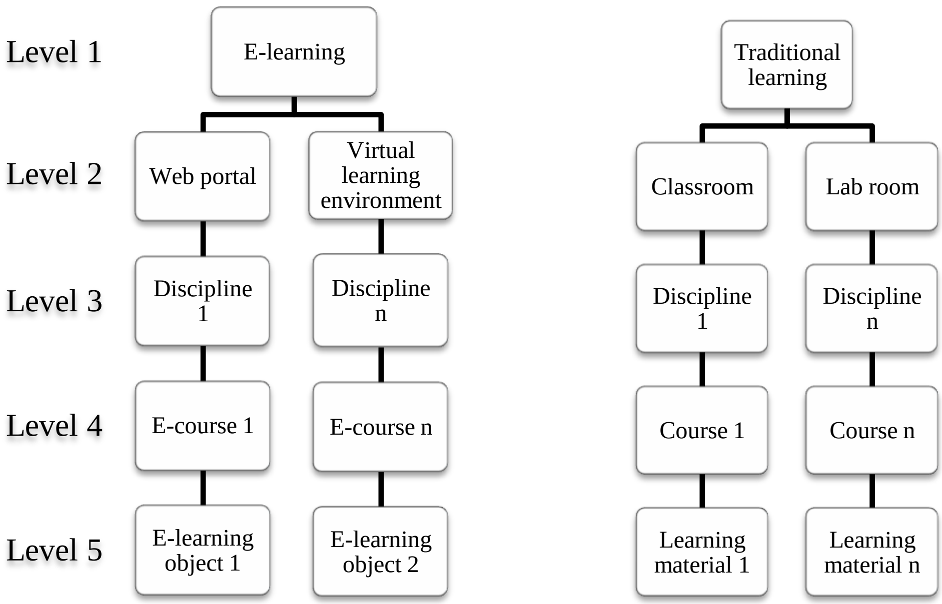

Figure 8. Learning objects.

5.1.3 Video Lectures

One of the main learning objects is the video lecture. In Figure 9 video lectures accessible by different modalities are illustrated.

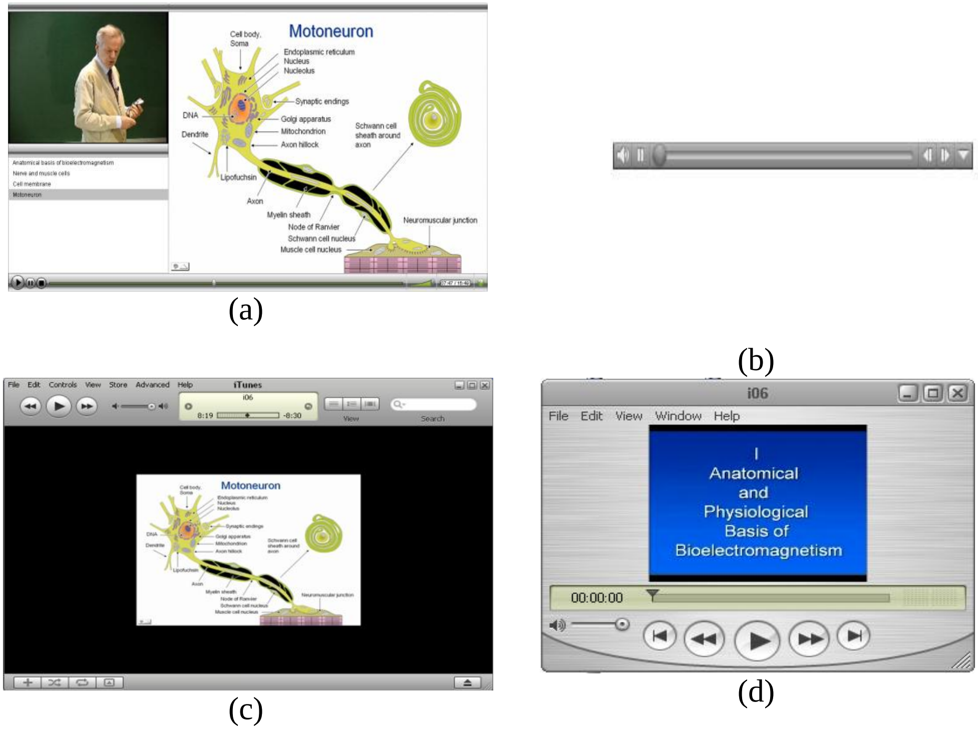

Figure 9. Examples of video lectures in different file formats. in (a) video lecture accessible with Pc, in Flash format. in (b) audio lecture accessible with mp3 player, in mp3 format. in (c) lecture for video player, accessible with iPod, in mv4 format. in (d) lecture accessible with media phone, in 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: 64kbits/ sec
	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 Kbits/sec
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 kbps
4.	Lecture for media phone	1584.81 sec	67,8 MB	.3gp	176x144px	Video codec: H.263 Frame rate: 15 Video bitrates: 261Kbit/ sec Aspect ratio: 1.22:1 Audio codec: AAC Audio bitrates: 95 Kbit/sec

5.2 EVALUATIVE PART

5.2.1 Evaluation based on students' opinions

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

- More students preferred traditional classroom learning (67%) than virtual learning (30%) and blended learning (3%). So students were quite conservative about innovations in learning.
- 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 how students evaluate usefulness of instructional materials. Naturally, traditional class students preferred live classroom lectures, virtual students - e-book and video lectures, blended class students found e-book and classroom lectures equally useful.
- The most useful learning elements based on students' opinions were animations, instructions in written format, learning materials in video format, exercises and queries on the web.
- Students would like that following resources were available in a virtual course: lecture handouts, virtual presentations (or videos), virtual laboratory works, virtual demonstrations and virtual exercises.
- Students would like to download video lectures to their PCs because they can be accessed multiple times and do not require Internet connection,
- Students who followed video lectures evaluated their audio quality, video quality, presentation and pedagogical value as quite high.
- Two types of problems prevented students from accessing video lectures: technical problems, i.e., slow Internet connection, no Flash player installed, or too 'old' laptop', and quite general problems, i.e., not familiar with the idea of video lectures or watching video lectures became dull and repetitive process.
- The main reason students indicated why they followed video lectures was to revise and review course material.

- The main reason why students did not followed video lectures was that they preferred traditional lectures more that recordings.
- Students would prefer live communication (i.e., face-to-face) or e-mailing with the educators and peers; asynchronous communication (i.e., online forums) and synchronous communication (i.e., audio/ video conference) would be less preferred.
- Several students' answers (20%) stated that availability of video lectures motivated them to skip traditional classroom lectures.
- Majority of students (79%) agreed that the English language is suitable for virtual learning. Thus, about 1/4 of students would like to get some help in native language, e.g., subtitles.
- Feedbacks revealed that virtual education was quite new endeavor for students. Only several students (40%) participated in virtual courses before.
- Web-logins analysis showed that virtual users accessed learning material every weekday. Meanwhile traditional classroom lectures were available only few hours per week.

Since the students who responded to questionnaire were able to choose whether to be anonymous or not, only 44% indentified their names. Based on that it was possible to compare their preferred learning methods and final examination results. We separated these students as traditional classroom, virtual class and blended class students. Their final exam results appeared to be very similar, Figure 10 and Figure 11.

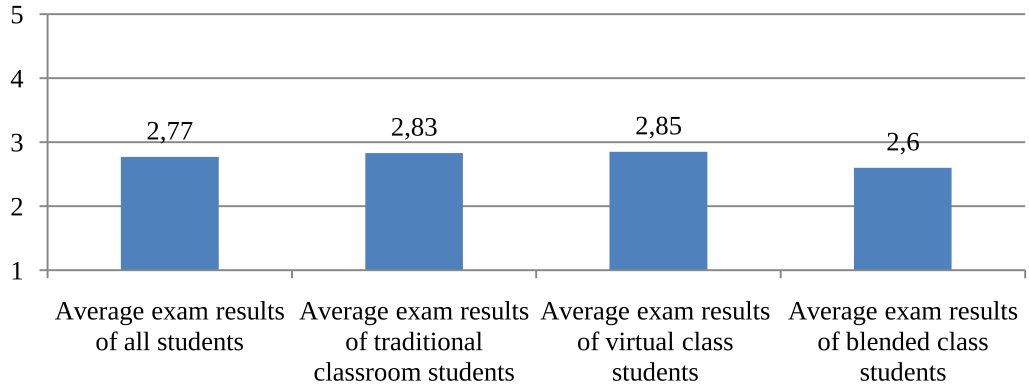

Figure 10. Comparing results of final examination, Autumn 2007.

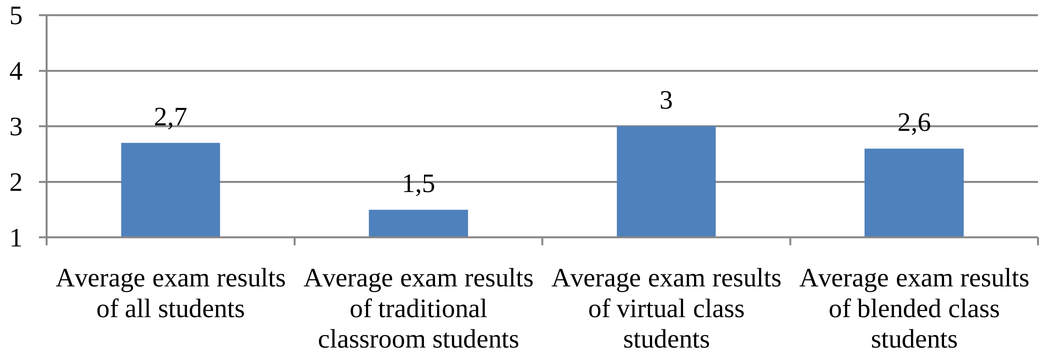

Figure 11. Comparing results of final examination, Autumn 2009.

5.2.2 Evaluation based on virtual users' opinion

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

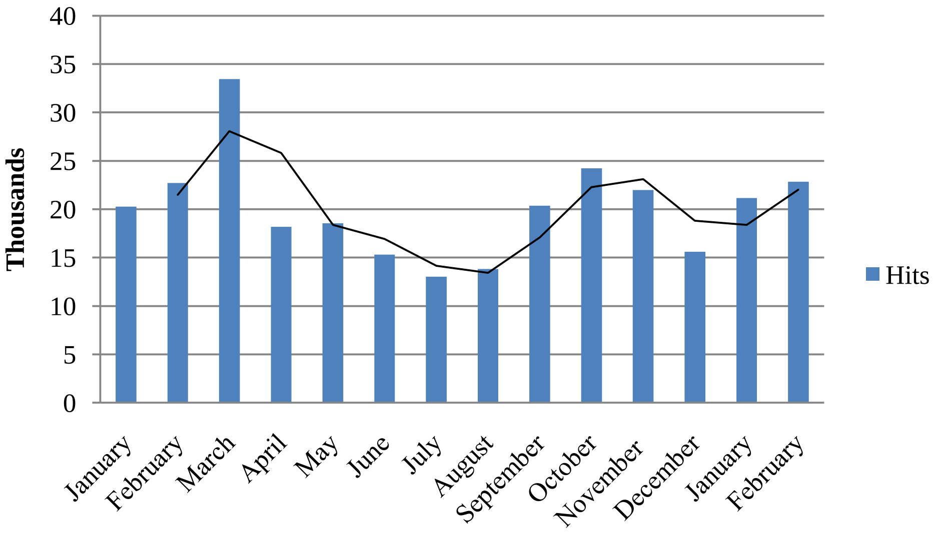

Figure 12. Number of hits for each month, 2009 and January-February, 2010.

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

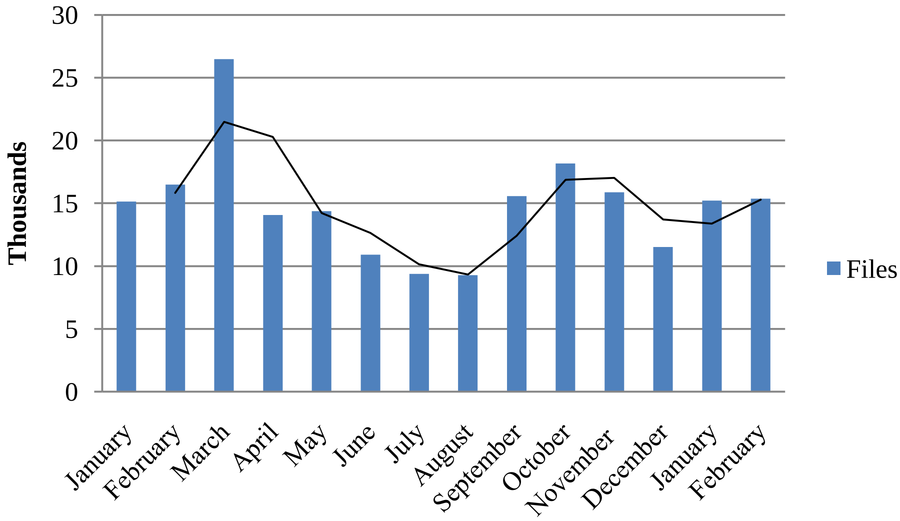

Figure 13. Number of requests (files) that resulted in something being sent back to the user for each month, 2009 and January-February, 2010.

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.

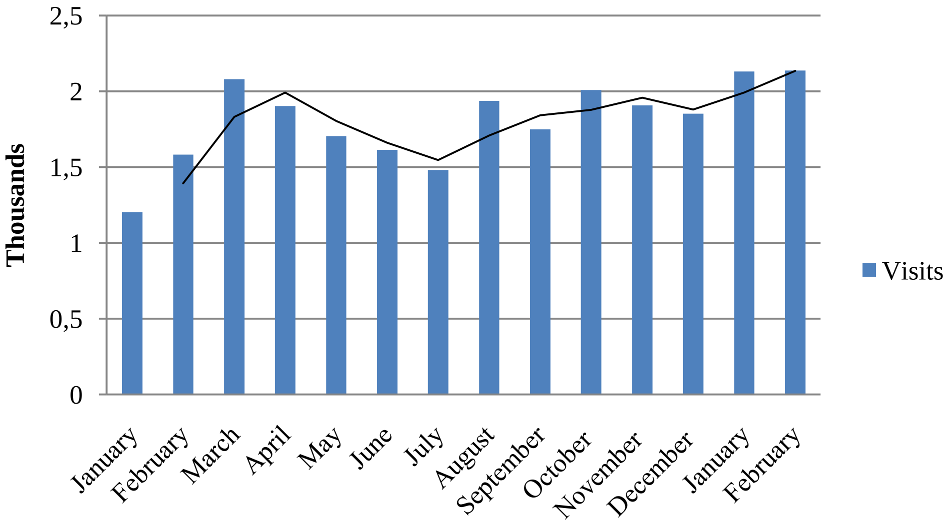

Figure 14. Number of visits for each month, 2009 and January-February, 2010.

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

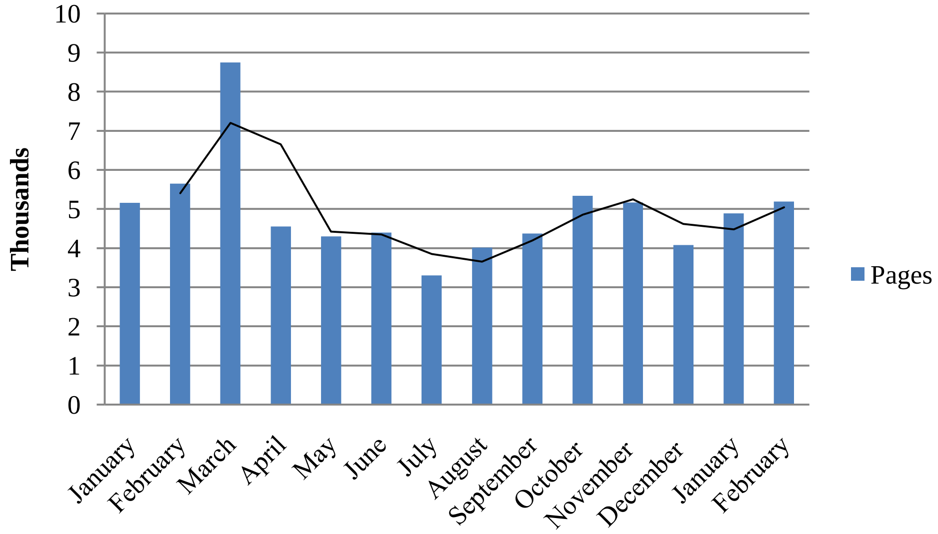

Figure 15. Number of page views for each month, 2009 and January-February, 2010.

A 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.

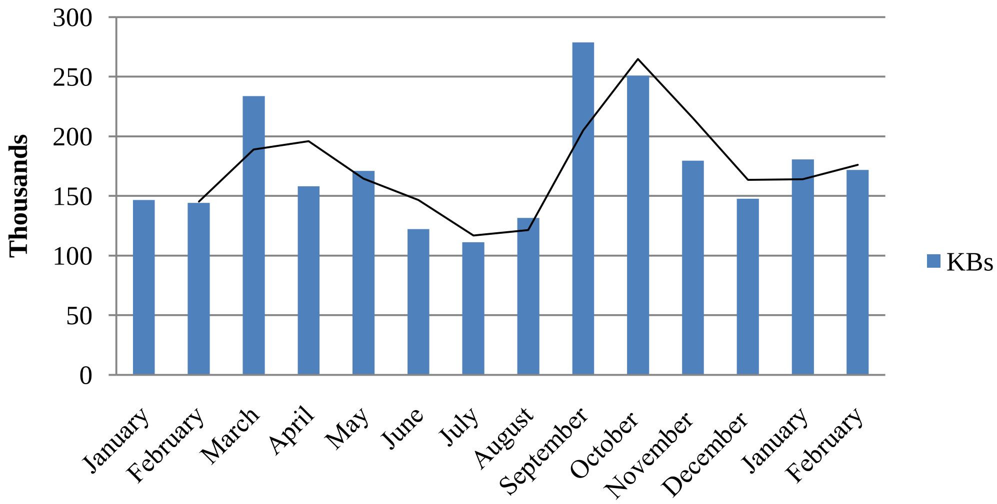

Figure 16. Total amount of data transferred from the server to machines each month, 2009 and January-February, 2010.

Figure 17 illustrates average number of visits during weekdays. Linear trend line shows that number of visits is increasing in the beginning of a week.

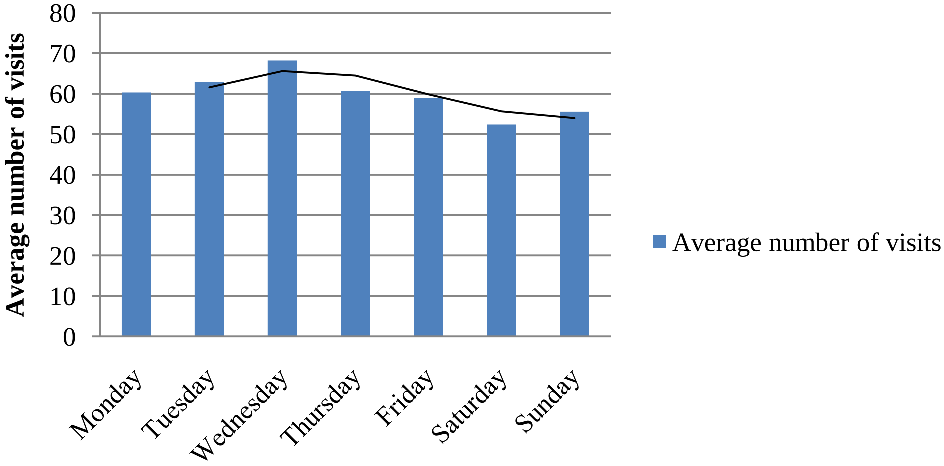

Figure 17. Average number of visits during weekdays, each month 2009 and January-February, 2010.

Figure 18 illustrates average number of virtual visits at 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.

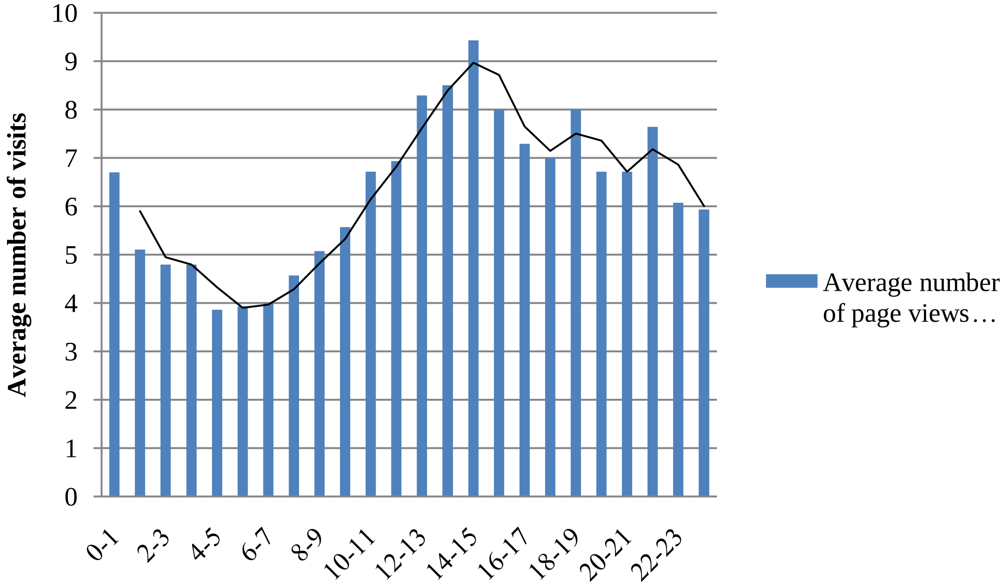

Figure 18. Average number of virtual visits at certain hour, each month 2009 and January-February, 2010.

It was possible to find out the amount of information transferred to the users from the server in KBs. Naturally; video lectures have been transferred the most from the server.

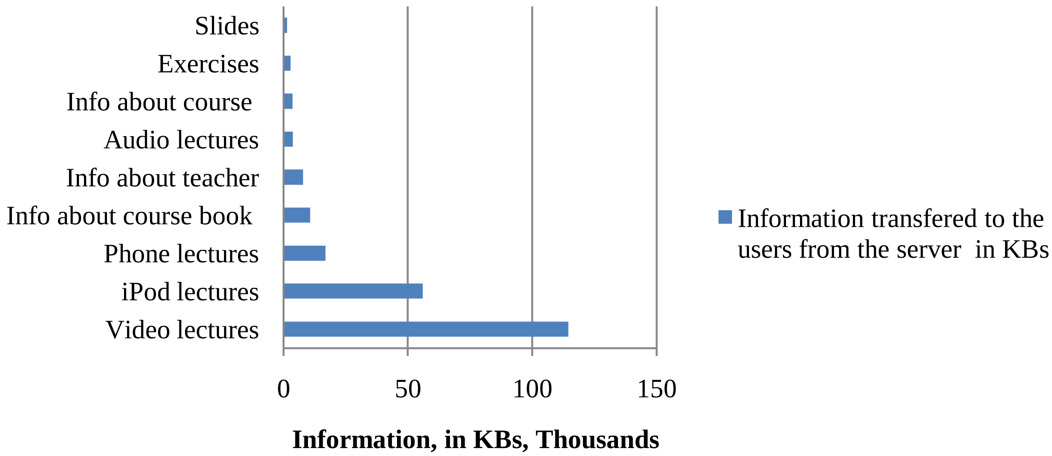

Figure 19. Amount of information transferred to the users from the server in KBs.

5.3 DEVELOPMENTAL PART

Data about e-learning development within BME discipline in Europe was obtained by administering questionnaire to the international BME education offering centers.

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

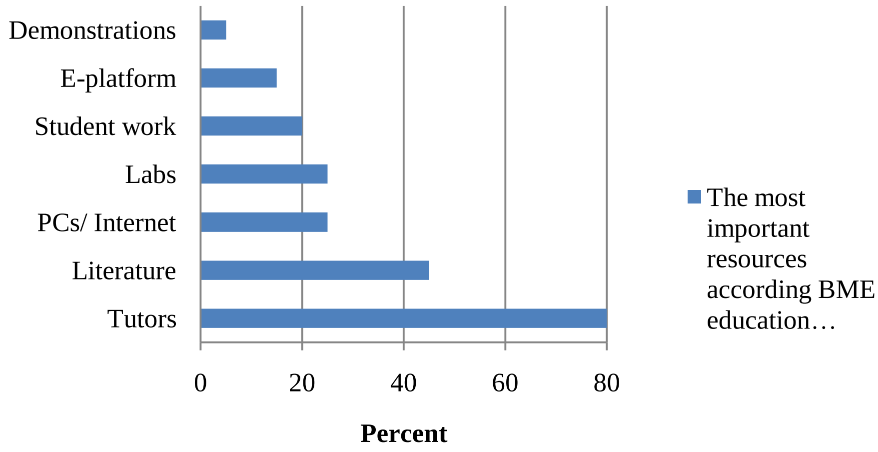

Figure 20. The most important resources supporting student learning according European education centers offering BME courses.

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

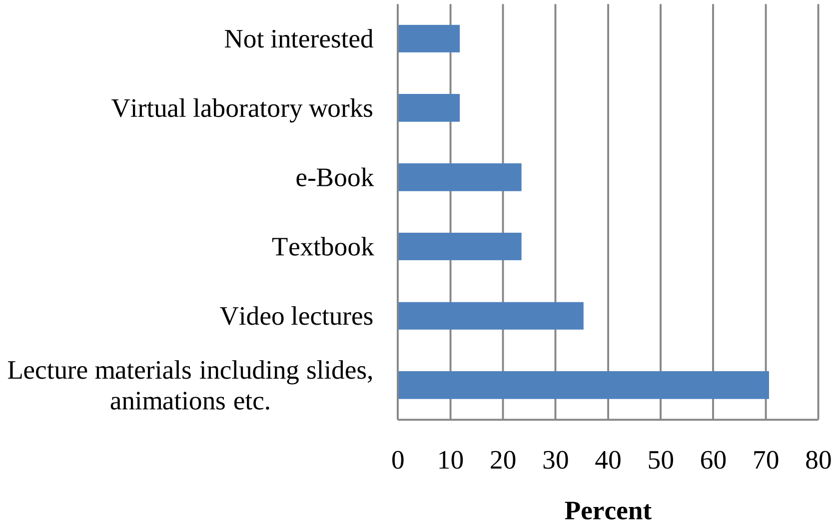

Figure 21. Resources that BME educators are able to provide to the virtual campus.

BME students would like to have lecture handouts, video lectures and laboratory works in a virtual course.

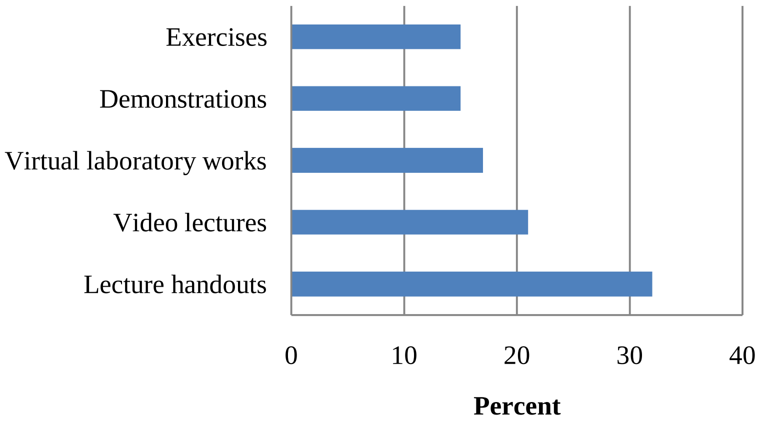

Figure 22. The most important resources supporting virtual courses according BME students.

Majority of BME e-course are at MSc level.

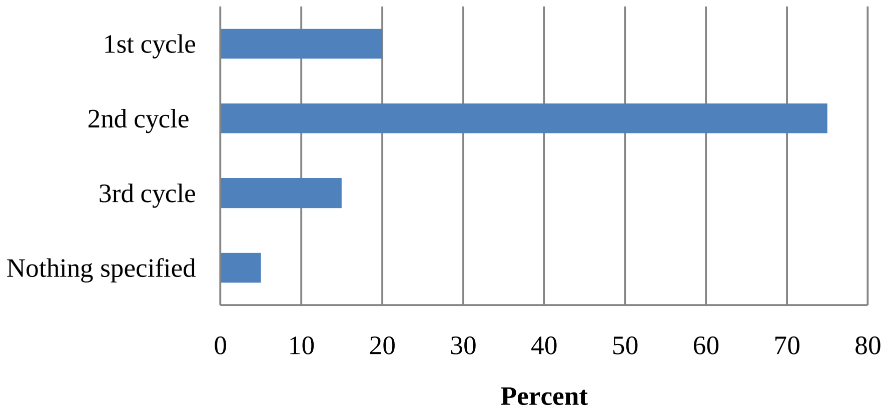

Figure 23. Most of the course that European education centers offer are at MSc level.

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

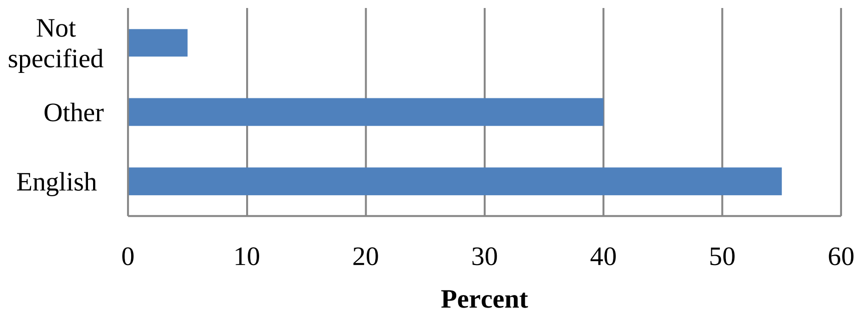

Figure 24. Languages of the courses that European education centers offering BME education provides.

6. DISCUSSION

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 & Lord 2000).

There have been done many different studies about future education; Felder & Silverman (1988) recommends teaching techniques for educators that address different learning methods, 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 in other courses, and to 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 illustration of intuitive patterns, i.e., logical inference, pattern recognition, generalization, and sensing patterns, i.e., observation of surroundings, empirical experimentation, attention to details, and encourage all students to exercise both patterns.
- Follow the scientific method 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, hands-on
- 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 experiences 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 aid when developing video lectures. The list of 9 principles includes 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 bit-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 than they are asynchronous.
- The design of multimedia presentation can have different effects on people based on their prior knowledge, visual literacy, and spatial aptitude.

The analysis of impact of ICT on education revealed that:

- The availability or use of computer does not have an impact on student learning.
- Computers have a positive impact on student attitudes and the learning of new kinds of skills, when ICT is used in conjunction with student-centered pedagogy.
- Teacher training is important. Through it, teachers can learn ICT skills and new pedagogical skills and these often result in new classroom practices.
- ICT can also be used to launch innovation in schools and provide communities with new educational services.

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 & Pohjolaine). Whether or not web-based learning can be considerable successful and worth the investment will largely depend on the value and goals of organization (Bartolic-Zlomislic & Bates, 2002). Cornford (2002) has pointed out that it is important to see virtual education as extended across the whole of university. The virtual education is not just a matter of flexible teaching and learning systems but extends into administration, students recruitment, research networks and library systems.

The future research in this field could concentrate on developing more advanced learning objects. Future learning objects should motivate students and provide possibilities to test their individual knowledge, e.g., creating more intelligent and adaptable learning, e.g.,:

- 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 25 and 26).

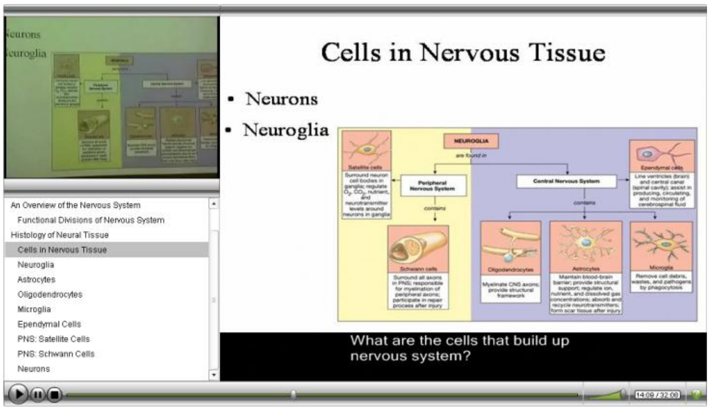

Figure 25. Video lectures with subtitles, e.g., in different native languages.

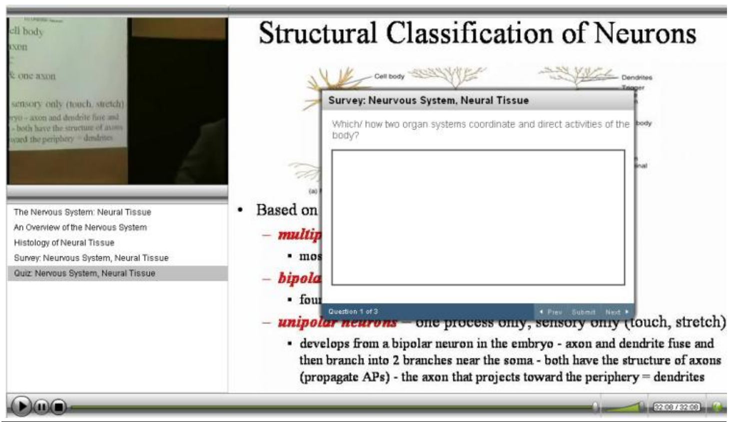

Figure 26. Video lectures with questionnaires and surveys at certain points.

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:

- 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 virtual campus achieve very similar results (i.e., learning outcomes).
- Students learn in the virtual campus 24 / 7, 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*, 13(2). Available at: http://www.springerlink.com/content/p8x03ku047401745/ [Accessed April 16, 2009].

Anohina, A., 2005. Analysis of the terminology used in the field of virtual learning. *Educational Technology & Society*, 8(3), 91-102.

Aroyo, L. & Dicheva, D., 2004. The new challenges for e-learning: the educational semantic web. *IEEE Journal of Educational Technology & Society*, 59-69.

Barrett, B., 2009. The Webalizer. Available at: http://www.mrunix.net/webalizer/.

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

Benkeser, P., 2006. Biomedical engineering education. In *Encyclopedia of*

Medical Devices and Instruments. John Wiley & Sons, Inc.

BIOMEDEA, 2005. *Biomedical Engineering Education in Europe - Status Report*, Available at: http://www.imt.liu.se/edu/Bologna/bologna/Status%20Reports%20on%20BME%20in%20Europe.pdf.

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

Boulos, M.N.K., Maramba, I. & Wheeler, S., 2006. Wikis, blogs and podcasts: a new generation of Web-based tools for virtual collaborative clinical practice and education. *BMC Medical Education*, 6, 41.

Caruana, C., 2009. Biomedical physics education for diagnostic and therapeutic radiographers in Europe - a review. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 123-126.

Caulfield, J., 2007. 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*, 1(1). Available at: http://academics.georgiasouthern.edu/ijsotl/v1n1/caulfield/IJ_Caulfield.pdf.

Chan, T. et al., 2001. Four spaces of network learning models. *Computers & Education*, 37(2), 141-161.

Chandrasekhar, A.J. & Jr, R.N.P., 1989. Interactive Video in Medical Education. *Proceedings of the Annual Symposium on Computer Application in Medical Care*, 1039–1040.

Christofides, S. et al., 2009. Education and training of the medical physicist in Europe. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 1-4.

Cloete, E., 2001. Electronic education system model. *Computers & Education*, 36(2), 171-182.

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

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

Duhaini, I., 2009. Medical physics status in the Middle East Countries. In *WC 2009, IFMBE Proceedings 25/XII*. Munich.

Duncan-Howell, J. & Lee, K., 2007. 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.

Eaton, K.A., Reynolds, P.A. & Cox, M.J., 2008. Top of the pops - CD-ROM and DVDs in dental education. *Br Dent J*, 204(4), 203-207.

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

ENQA Secretariat, 2009. The European Association for Quality Assurance in Higher Education. Available at: http://www.enqa.eu/.

EU Commission, 2010. EUR-Lex - 52009DC0390 - EN. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0390:FIN:EN:HTML [Accessed April 6, 2010].

Felder, R. & Silverman, L., 1988. Learning and teaching styles in engineering education. *Engr. Education*, 78 (7), 674-681.

Fominykh, M. et al., 2008. Virtual campus as a framework for educational and social activities. Available at: http://www.idi.ntnu.no/grupper/su/publ/fominykh/fominykh-cate08.pdf.

Funderstanding, Neuroscience. Available at: http://www.funderstanding.com/content/neuroscience [Accessed April 6, 2010].

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

Guangzou, C. et al., 2006. E-Learning evolution: from m-learning to educational semantic web and beyond. *Frontiers in artificial intelligence and applications*, 151, 7-14.

Gwo-Jen Hwang, 2006. Criteria and Strategies of Ubiquitous Learning. In *Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006. IEEE International Conference*. Sensor Networks, Ubiquitous, and Trustworthy Computing, 2006. IEEE International Conference on. pp. 72-77.

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

Harris, T.R. & Brophy, S.P., 2005. 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*, 27(7), 617-624.

Holmes, A.(.A. & Brown, S., 2000. *Internal audit in higher education*,

Kaur, P. et al., 2005. The Combination of Different Modalities in the Web-Based Learning Environment: A Comparative Analysis of the Perceptual Instructional Outcomes. In *Advanced Learning Technologies, IEEE International Conference on*. Los Alamitos, CA, USA: IEEE Computer Society, pp. 764-768.

Keegan, D., 1994. *Foundations of distance education*, Routledge. Available at: http://books.google.com/books?id=Ab4NAAAAQAAJ [Accessed May 30, 2009].

Khambete, N., 2009. Biomedical engineering education and training in India - a need for new approach. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 368-371.

Krisanachinda, A. et al., 2009. Medical physics education and training in south east Asia. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 143-145.

Kulik, C.C. & Kulik, J.A., 1991. Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior*, 7(1-2), 75-94.

LaPlaca, M., Newstetter, W. & Yoganathan, A., 2001. Problem-based learning in biomedical engineering curricula. In *Frontiers in Education Conference, 2001. 31st Annual*. Frontiers in Education Conference, 2001. 31st Annual. pp. F3E-16-21 vol.2.

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

Lechner, S., 2001. Evaluation of teaching and learning strategies. *Med. Educ. Online*, 6(4). Available at: http://med-ed-online.org/f0000024.htm [Accessed May 12, 2009].

Lee, J., Hong, N.L. & Ling, N.L., 2001. An analysis of students' preparation for the virtual learning environment. *The Internet and Higher Education*, 4(3-4), 231-242.

Linsenmeier, R., 2003. What makes a biomedical engineer? *Engineering in Medicine and Biology Magazine, IEEE*, 22(4), 32-38.

Llanusa, S. et al., 2009. Improving the methodological approach to evaluate the use of information and communication technologies in primary helath care in Cuba. In *WC 2009, IFMBE Proceedings 25/XII*. Munich.

Luppicini, R., 2005. A systems definition of educational technology in society. , 8(3), 103-109.

Magennis, S. & Farrell, A., 2005. Teaching and learning activities: expanding the repertoire to support student learning. *Emerging issues in the practise of university learning and teaching*. Available at: http://www.aishe.org/readings/2005-1/magennis.html.

Malmivuo, J., 2007. Evicab. *http://ww.evicab.eu*. Available at: http://www.evicab.eu/ [Accessed May 31, 2009].

Malmivuo, J., Nousiainen, J. & Kybartaite, A., 2008. Biomedical engineering program on the Internet for worldwide use. *14th Nordic-Baltic conference on biomedical engineering and medical physics*, 5-

7.

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

Mayer, R.E., 2005. *The Cambridge handbook of multimedia learning*, Cambridge University Press. Available at: http://books.google.lt/books?id=SSLdo1MLIywC [Accessed May 31, 2009].

Mochimaru, Y. et al., 2009. The enhancement of the radiotherapy resources in Osaka, Japan; based on the Japanese structure survey in 2003 and 2005. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 332-335.

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

Mukhtar, S. et al., 2009. Biomedical engineering instrumentation research collaboration between Universiti Kuala Lumpur deNuo Sdn. Bhd. and Flinders University, Australia.

Nagel, J.H., 2007. BIOMEDEA. In *11th Mediterranean Conference on Medical and Biomedical Engineering and Computing 2007*. pp. 1118-1121. Available at: http://dx.doi.org/10.1007/978-3-540-73044-6_289 [Accessed August 7, 2009].

Nagy, A., 2005. The Impact of E-Learning. In *E-Content*. pp. 79-96. Available at: http://dx.doi.org/10.1007/3-540-26387-X_4 [Accessed January 28, 2010].

Newstetter, W. & Yoganathan, A., 2002. Supporting complex problem solving in BME education. In *[Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint*. [Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society] EMBS/BMES Conference, 2002. Proceedings of the Second Joint. pp. 2603-2604 vol.3.

Nkuma-Udah, K., Okoye, G. & Ndubuka, G., 2009. Biomedical engineering education and training in Nigeria.

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

Opentraker.net, 2009. Opentraker.net. Available at: http://www.opentracker.net/index.jsp.

Palmer, E.J. & Devitt, P.G., 2007. A method for creating interactive content for the iPod, and its potential use as a learning tool: Technical Advances. *BMC Medical Education*, 7, 32.

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

Prince, M., 2004. Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.

Rae, W., 2009. Status of education and training in Africa: focus on south Africa. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 25-27.

Richardson, J.T., 2005. Instruments for obtaining student feedback: a review of the literature. *Assessment & Evaluation in Higher Education*, 30(4), 387-415.

Richey, R., Ely, D. & Silber, K., 2008. Reflection on the 2008 AECT definitions of the field. *TechTrends*, 52(1), 24-25.

Rocard, M. et al., 2007. *Science education now: a renewed pedagogy for the future of Europe*, European Comission, High Level Group on Science Education.

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

Schreuders, P. & Johnson, A., 1999. A system approach for bioengineering. *Int.J. Engng Ed*, 15 (4), 243-248.

Schreurs, B. et al., 2009. *Reviewing the virtual campus phenomenon. The rise of large-scale e-learning initiatives worldwide.*, Heverlee.

Shah, A. & Hamid, A., 2009. Assessment and development of competency of clinical engineering practitioners - south east asian experience. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 324-326.

Song, L. & Hill, J., 2007. A conceptual model for understanding self-directed learning in online environment. *Journal ofInteractive Online Learning*, 6(1), 27-42.

Stefanoyiannis, A. et al., 2009. Education and training of Medical Physicists in Europe and the countries of north America: similarities-differences-general guidelines. In *WC 2009, IFMBE Proceedings 25/XII*. Munich.

Suh, T., 2009. The current status of medical physics in Asia-Oceania. In *WC 2009, IFMBE Proceedings 25/XII*. Munich.

Weng, X., Niu, W. & Fan, Y., 2009. Educational development of biomedical engineering in china. In *WC 2009, IFMBE Proceedings 25/XII*. Munich, pp. 101-104.

Williams, J. & Fardon, M., 2007. Perpetual connectivity: lecture recordings and portable media players. In *Proceedings ascilite Singapore 2007*. Available at: http://www.ascilite.org.au/conferences/singapore07/procs/williams-jo.pdf.

Volery, T. & Lord, D., 2000. Critical success factors in online education. *International Journal of Educational Management*, 14. Available at: http://www.emerald-library.com.

Zhang, D. et al., 2004. Can e-learning replace classroom learning? *Commun. ACM*, 47(5), 75-79.

M. Fominykh. ED MEDIA – 2009. “Virtual Campus in the Context of an Educational Virtual City: a Case Study.

The Whitaker Foundation. [Internet]. Available: http://bmes.seas.wustl.edu/WhitakerArchives/glance/definition.html. Accessed: 15.2.2010

9. ORIGINAL PUBLICATIONS