



WP4: Final report

Review of e-teaching/ e-learning Practices and Technologies

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Report

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ABSTRACT	
<p>Biomedical engineering education brings together knowledge from many different sources: biological sciences, medicine, and engineering. Due to such diversity it requires special teaching and learning approaches. E-learning can offer significant advantages over traditional education, e.g., providing organized access to many resources, more flexible and superior quality delivery structures and new learning opportunities.</p> <p>E-learning strategies and methods have been reviewed in WP4. Different Virtual Learning Environments (VLE), e-tools and techniques that can support e-learning were analyzed. The review revealed that there exist theoretical and practical possibilities to create high quality e-learning education for biomedical engineering. Several recommendations are presented at the end of the report.</p>	
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1 Introduction

Biomedical engineering brings together knowledge from many different sources: biology, medicine, and engineering. The field of biomedical engineering requires specific learning and teaching methods where learning outcomes depend a lot on student's learning style. E-learning environments can offer significant advantages over traditional learning, e.g. provide organized access to many resources, more flexible delivery of learning material and new learning opportunities.

E-learning is based on different learning theories. A great deal of research has gone into teaching and learning theories over the years. Although there are a variety of learning theories, the following three are the most significant [1], [2]: a) behaviourism – focuses on repeating a new behavioural pattern until it becomes automatic; b) cognitivism – is similar to behaviourism in that it stresses repetition, but it also emphasizes the cognitive structures through which people process and store information; c) constructivism – states that knowledge is constructed through an active process of personal experience guided by the learner himself/herself.

Learning may be thought as a two-step process involving the reception and processing of information [3]. In the reception step, external information (observable through the senses) and internal information (arising introspectively) become available to students, who select the material they will process and ignore the rest. The processing step may involve simple memorization or inductive or deductive reasoning, reflection or action, and introspection or interaction with others. The outcome is that the material is either “learned” in one sense or another or not learned.

A learning-style model classifies students according to where they fit on a number of scales pertaining to the ways they receive and process information. A student's learning style may be defined in large part by the answers to four questions [3]:

- 1) What type of information does the student preferentially perceive: sensory (external) – sights, sounds, physical sensations, or intuitive (internal) – possibilities, insights, hunches?
- 2) Through which sensory channel is external information most effectively perceived: visual – pictures, diagrams, graphs, demonstrations, or auditory – words, sounds?
- 3) How does the student prefer to process information: actively – through engagement in physical activity or discussion, or reflectively – through introspection?
- 4) How does the student progress toward understanding: sequentially – in continual steps, or globally – in large jumps, holistically?

Applying corresponding teaching style to the corresponding learning style the biggest learning effect can be achieved.

2 E-learning methods and technologies

2.1 E-learning environments

There are two general types of Web-based learning environments [1]: synchronous and asynchronous.

A synchronous learning environment is one in which an instructor teaches a somewhat traditional class but the instructor and students are online simultaneously and communicate directly with each other. Software tools for synchronous e-learning include audio

conferencing, video conferencing, and virtual whiteboards that enable both instructors and students to share knowledge.

In an asynchronous learning environment, the instructor only interacts with the student intermittently and not in real time. Asynchronous learning is supported by such technologies as online discussion groups, email, and online courses.

E-learning environments typically provide the following capabilities for management, development and delivery of e-learning [1]:

- **Map Competencies to Courses:** An administrator can describe the competencies (skills) necessary for selected jobs within an organization and describe the learning content (courses) that will teach that skill.
- **Schedule Classes/Register Students:** An administrator can schedule synchronous classes or post links to courses for asynchronous classes. Students can register for synchronous and asynchronous classes.
- **Track Learning:** The system can track which classes a student takes and how the student scores on the assessments in the class.
- **Develop Learning Content:** Authors are provided with software tools for creating asynchronous courses made up of reusable learning objects.
- **Deliver Learning Content:** Asynchronous courses or individual learning objects that have been stored on the server are delivered to students via a Web browser client.

2.2 Key components of e-learning courses

Creating an e-learning course to achieve specified outcomes requires effort in three domains—same as for not online course (see Figure 1) [1]: 1) planning (identifying course content and defining measurable learning objectives for it); 2) instruction (selecting and implementing the methods that will be used to deliver the specified content and facilitate student achievement of the objectives); and 3) assessment and evaluation (selecting and implementing the methods that will be used to determine whether and how well the objectives have been achieved and interpreting the results). As is shown in Figure 1 the three stages are not purely sequential—the information collected in each of them feeds back to each of the others in a cycle that leads to continuous improvement. If the assessment reveals that an objective has not been satisfactorily achieved, the nature of the failure may suggest reframing the objective or modifying the instruction used to address it. Similarly, as the quality of the instructional program improves, new objectives may be formulated to encompass higher levels of achievement and the course instruction and assessment modified accordingly.

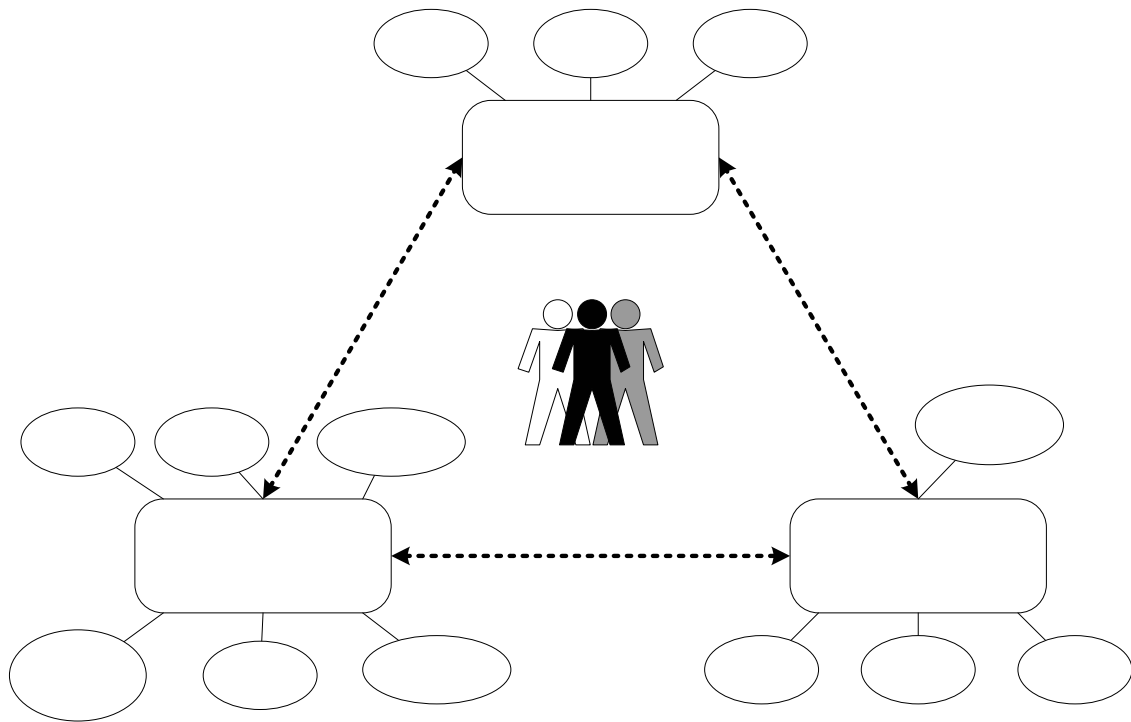


Figure 1 Elements of the course design (adopted from [1])

Six-element typology of teaching tasks and objectives can be used then designing e-learning courses [2]: 1) attention, 2) perception and recall, 3) organization and sequencing, 4) instruction and feedback, 5) learner participation, and 6) higher order thinking and concept formation. The following media and modes are considered because they are common and familiar, and also because they constitute the tools most available to online teachers, trainers, and learners: 1) print and text, 2) still graphics and illustrations, 3) sound and music, 4) video and moving graphics, and 5) multimedia.

2.3 E-learning standards

Standardization efforts for learning technology began as early as 1988 in the form of specifications for hardware and software platforms. The Internet and the World Wide Web shifted the focus of these standardisation efforts to specifications of Internet protocols and data formats [1].

E-learning standards are being developed by four main organizations: Aviation Industry CBT Committee (AICC) [4], IMS (Instructional Management System) Global Learning Consortium [5], Advanced Distributed Learning (ADL) Initiative [6], and IEEE [7]. In the last years, these four organizations have begun to harmonize their specifications. The Sharable Content Object Reference Model (SCORM) specification from ADL is the result of this harmonization.

SCORM [8] assumes a Web-based infrastructure as a basis for its technical implementation. SCORM provides a specification for construction and exchange of learning objects, which are called Sharable Content Objects (SCOs) in the SCORM specification. SCORM does not address interoperability for the delivery of synchronous e-learning. It only addresses interoperability for asynchronous e-learning. In particular, it addresses the structure of online courses, the interface to a repository for accessing online courses, and the protocol for launching online courses and tracking student progress and scores.

Instructional
technology
Labs

2.4 Virtual learning environments

A virtual learning environment (VLE) is a software system designed to facilitate teachers in managing educational course for their students. It is a primarily tool for distance education used to supplement the face to face classroom. VLE is built on a two key elements: computer technology and education. There exist hundreds of VLE's. These references [9],..., [22] represent not very exhaustive list. However, there are only a few main competitors that surveys show the most popular. UK survey (2005) [23] shows BlackBoard, WebCT (commercial systems) and Moodle (open source system) most frequently used. Swiss survey (2006) [24] points out the same systems, but in different order: WebCT, Moodle, BlackBoard. Recently, BlackBoard acquired WebCT company. Thus, it can be expected, in the future, two main players: BlackBoard and Moodle will be left. Though, appearing interoperability standards of learning systems can boost the development of new systems and successive competitors.

2.4.1 VLE comparison

There are some web sites dedicated to analysis and comparison of different VLE [24], [26], [27].

The analysis of most popular VLE's (BlackBoard, WebCT, Moodle) suggests these systems being similar in nature. All of them have basic components and most of advanced. The differences are found in layout of user interfaces, in integration level of different tools and feature richness. For example, WebCT has high level integration of the grade book in the system. Grade book is supported by customizable grading forms or rubrics. Thus it is easy to evaluate or assess student's participation in the discussion forum or assignments according to grading forms. The grades automatically appear in grading book. Some VLE's have more modern functionalities. For example, Moodle has modern communication and content management features "Blogs" and "Wikis", supports RSS.

The source [26] provides most up to date information about commercial and open source VLE's. It is possible to select several VLE's from the list of 14 systems and accomplish side by side comparison according to these aspects: Communication Tools, Productivity Tools, Student Involvement Tools, Administration Tools, Course Delivery Tools, Content Development Tools, Hardware/Software.

2.4.2 VLE tools

The source [25] proposed a model which covers three main areas of functionality of any e-learning platform: content, communications, and management:

- **Content:** this includes tools that enable the delivery of electronic learning content.
- **Communications:** this area covers electronic tools that support any type of communications and group work.
- **Management:** this includes any tools or systems that support the management of the teaching and learning process.

The modern VLE systems usually have three types of users: tutors (teachers), learners (students) and administrators (designers). The users have different views of the system and different rights to the tools

The VLE tools support student learning in many ways:

- **Communication.** Communication tools support communication between students and tutors, between students and students or across student groups through

synchronous (or real-time) chat and asynchronous online discussions tools. Other communication tools include online calendars, diaries or timetables. These can provide an overview of key events during courses and might include submission dates for assessments. VLEs may have email facilities which can be used for communicating on a one-to-one or one-to-many basis. However, usually students log on to a number of other email systems, including their institutional account. Therefore students may not wish to access the VLE email account and learn to use yet another system. To overcome this problem, some VLE systems allow email forwarding to configured most frequently used email box, so that students and tutors always get informed;

- **Assessment.** VLEs have tools for formative and summative assessment. Self-tests can be used by students for quick concept-checking and 'formative' feedback. Quizzes can provide guidance for both the tutor and the students; the results can highlight key areas that have not been fully understood by the student and which the tutor or teaching team can then cover in later sessions, online or face-to-face. Tutor feedback provided in these assessment tools is a key element in helping students to develop an understanding of a subject. Summative assessment is implemented through graded quizzes and assignments. The Grading forms tool provides a more granular way of grading Students' work by identifying specific criteria and levels of performance against the criteria. Some of the benefits of using a grading form include: performance expectations are clear (students can view the criteria when completing the work), grading is consistent (section Instructors and Teaching Assistants use the criteria when grading the work), feedback is structured (along with their final mark students can view the completed grading form to see how they scored for each criterion.
- **Collaboration.** There are tools that can support collaboration within and across student groups. For example, the file upload facilities in a VLE allow tutors and students to share resources by moving learning materials (for example articles, notes, images, PowerPoint files, etc) into the VLE. Whiteboard software is a useful way of 'visualising' ideas and concepts. This software allows students to draw images collaboratively or, alternatively, to upload images and discuss them using chat facilities (text or audio communication) while simultaneously viewing the image.
- **Other facilities.** Other facilities which may be available in a VLE include student tracking which will provide tutors with information about when a student first accessed a course, how frequently they have accessed it and which areas they have accessed. VLEs can be linked (either directly or via a web link) to other online learning tools, which are not part of the VLE, for example concept mapping, interactive JAVA simulators in other web sites, see [25].

As an example, we list here some of features supported by Moodle:

- Forums: an online discussion groups where participants can exchange open messages.
- List servers: an automatic mailing list; when e-mail is addressed to listserv mailing list, it is automatically broadcasted to everyone on the list.
- Content managing – supports display of any electronic content, Word, PowerPoint, video, sound, etc., that is stored locally or remotely. Files can be uploaded and managed.
- Tests with different kinds of questions: possibility for student's self-assessment.

- Blogs: an internet web page that can serve as a publicly accessible personal journal for an individual.
- Wikis: a collaborative Web site that comprises the perpetual collective work of many authors; a wikis allows anyone to edit, delete or modify content that has been placed on the web site, including the work of previous authors.
- Surveys: analysis of online classes
- Chat: smooth, synchronous text interaction
- Glossaries: an alphabetic list of terms in specialized field of the course.
- Peer assessment: allows peer assessment of documents; teacher can manage and grade the assessment.
- FAQ: frequently asked questions
- Multi-language support (over 60 languages)

Moodle's infrastructure supports:

- User authentication methods: a user (student, e-tutor, and administrator) can log in with personal password and apply or modify the material which is in VLE.
- Enrolment methods: enrolment form is filled before giving a password and right to access the material in VLE. Roles for specific participants can be defined for each course.
- Content filters: all information placed on VLE can be filtered.
- User's activity: reports for each student are available with graphs and details about each module (last access, number of times read) as well as detailed 'story' of each student's involvement including posting on the web. This information is relevant for assessment.

2.5 Tools for authoring of e-learning materials

E-learning authoring tools enable teachers to integrate an array of media to create professional, engaging, interactive training content, and make it possible to repurpose digitized elements or learning objects from an existing course for reuse in a new one. Currently available tools offer a variety of features. For example, some tools are designed to develop extensive assessments, software simulations, or content for hand-held computers. However, most tools are designed to create basic e-learning courses for desktop or laptop computers. The software programs support a variety of media and file types, such as text, graphics, video, and audio. Most include assessment and test creation features.

The following points should be considered identifying the capabilities and options that are most important then choosing authoring tools [28]:

- *Ease-of-use versus creative freedom.* There are template-based tools that require practically zero training. These programs are highly formatted, with a course development process that's driven by a sequence of dialog boxes. Unfortunately, the programs have limited flexibility. They are good then ease-of-use is more important than creativity. Other authoring tools require more training but offer extended creative latitude. Finally, there are authoring tools designed to produce high-end multimedia simulations with sophisticated graphics and audio. These tools generally

require several weeks to several months to learn, but they offer a great deal of creative freedom.

- *Automated programming.* By automating programming for online delivery, authoring tools liberate course developers from their dependence on programmers. A few authoring tools have the ability to write such programming languages as HTML, XML, or DHML. The types of programming code or output formats vary significantly among tools.
- *Interoperability and standards.* The ability of an authoring tool to work with other e-learning software and systems is referred to as interoperability. Successful interoperability is the result of software compliance to technology standards. The e-learning community has several sets of technology standards and is currently developing additional standards. The ultimate vision is to have interoperability throughout the entire e-learning market. If your organization currently is using a learning management system, determine whether the authoring tool you're considering is compatible with your LMS.
- *Multiple learning paths.* To accommodate differences among learners, some authoring tools have the capability to create variables, which is an important feature for adaptive learning. Think of an e-learning course as a linear path variables enable course developers to create forks in the path that send learners in different directions based on training criteria or responses to specific questions. Courses created using variables are more complex to design, but they account for a range of knowledge and skill sets.
- *Media and file support.* Most authoring tools support such common file types as JPGs, WAVs, and GIFs, while few packages support streaming video and audio.
- *Extensibility.* Some trainers need to customize the software for specific purposes. The ability to do that is called extensibility. If you or your organization requires some customization to the authoring software, be certain that you have a tool with open source code, which allows a skilled computer programmer to customize software to meet the trainer's needs.

Authoring tools for e-learning material creation could be grouped by the content type into two groups:

- Text tools
- Multimedia: video; audio; images, graphics.

The boundaries of such grouping in the last few years disappeared and we can state that there are just multimedia content development tools, because text, video, audio and graphics are blended.

According to the Learning Light organization [29] proposed classification, e-learning content development tools are classified in such way:

- Avatars (virtual characters) – are used for the production of specialist interactive and intelligent content in the form of virtual assistants, mentors etc.
- Blogging tools – are used to create blogs, mobile blogs, audio blogs (aka podcasts) and video blogs (aka vblogs).
- Course and lesson authoring tools – useful for the production of online lessons and courses.

- EPSS and Help tools – tools to performance support and online help tools.
- e-Book tools – useful for reading as well as creating e-books for your PC or mobile device.
- Forms, survey and polling tools – for creating online forms and surveys.
- Graphics and animation tools – used for the production of graphics, animation, pictures and for photo editing.
- Interactivity tools – tools for interactive e-learning
- PDF tools – tools for creating and viewing PDF (portable document files).
- Podcasting tools – tools for reading and creating podcasts as well as places to find podcasts.
- Presentation (& streamed presentation) tools – tools that can be used for the production of online presentations.
- RSS tools – tools that will help you create and read RSS feeds.
- Simulation/demonstration/screencasting tools – simulation and demonstration tools - aka Screencasting tools - for creating e-learning solutions.
- Testing, quizzing and gameshow tools – range of dedicated tools that are useful for the production of online tests, quizzes and games.
- Video tools – e.g., video to Flash converter tools, webcam as well as video blogging tools.
- Web page authoring tools – some general web authoring and site management tools, including hosted websites.
- Webcasting and streaming media tools – webcasting tools and software to create live, interactive web events as well as on demand streamed audio and video.
- Other content development tools – selection of miscellaneous tools for creating or managing the development of e-learning content solutions.

Long list of authoring tools with references and short descriptions is presented in [29].

E-learning and communication can be facilitated with free, open source tools. These tools make possible to share ideas and information with a wide audience, support and promote learning content.

2.6 Delivery methods of e-teaching materials

Text based e-teaching material is usually delivered as HTML, PowerPoint, or PDF documents. In addition there is a wide spectrum of other methods available [30]:

- *Hypertext material*: structured material is provided electronically and can be viewed with a browser. Hyperlinks connect text, multimedia, and exercises in a meaningful way.
- *Video based material*: like face-to-face classroom course, with recorded lecturer speaking and PowerPoint slides or online examples used to illustrate. Video streaming technologies are used. Students can watch the video by means of freeware or plug-ins (e.g., Windows Media Player or RealPlayer).

- *Audio based material*: the sound track of the lecturer is provided. Often the course pages are enhanced with a text transcription of the lecture.
- *Animated material*: enriching text-oriented or audio-based material by animations is generally a good way of making the content and its appearance more interesting. Animations are created using Macromedia Flash or similar technologies.
- *Web-supported textbook material*: based on specific textbook. Students read and reflect chapters themselves. Review questions, topics for discussion, exercises, case studies, etc, are given chapterwise on a website and discussed with lecturer or peers. For example, class meetings may be held to discuss matters in chat rooms.

2.6.1 Video lectures as e-teaching material

Video based lectures can be a powerful teaching tool [31]. They are growing in popularity within higher education [32], e.g., Massachusetts Institute of Technology [33], University of California, Berkeley [34], project Videolectures.NET [35]. The review of previously reported uses of videos defines three areas where they are especially effective [32]:

- To grab students attention and motivate them to learn. The primary aim is not to use videos to teach the material itself but “they can stimulate the interest” [36]
- To provide highly realistic depiction of reality which students would not otherwise have the opportunity to see, e.g. medical procedures.
- To watch again/ later recorded live face-to-face lectures.

Typically video based lectures are placed on the files server and students can connect to have them streamed to their PC whenever they want. A limited access, e.g., for approved class members can be established by placing video lectures in VLE, e.g., Moodle. Video lectures can be also available as CD or DVD format.

Video lectures are : a) when directed video camera towards lecturer capturing his/her speech and presentation, b) recorded lecturer and displayed presentation along side in separate frame, and c) recorded lecturer’s voice and captured graphic presentation.

Emerging technologies can automate the process insuring that lecturer needs minimal technical knowledge and spends no additional time creating recordings.

Benefits of video lectures are [32], [37]:

- Allow revisit any point of the lecture that student did not understand.
- Allow to stop, start, and rewind the video to address the specific need.
- Allow catching up if the student miss a face-to-face lecture
- Enable to adjust flexible learning patterns; student can choose when where to use the material and can spend as long or little time on each activity.
- Allow to improve preparation for assessment
- Provide opportunity to see an eminent speaker-lecturer who would not be able to travel to higher institution more than once to give the lecture.
- Allow to become self-sufficient learner
- Increase overall level of confidence with a course.

Negative aspects of video lectures:

- Possibility for adverse effect on attendance.
- Qualities of excellent public speaker can be lost when transferred to a video.
- The viewer is less forgiving of the lecturer's minor mistakes and audience disruption
- Learning experience can become dull and repetitive
- Video lectures can promote the transfer of knowledge facts, whilst diminish the importance of constructing knowledge.
- Large and long video files can cause problems to download
- Technical limitations and quality issues are not simple problem and enabling technologies are not yet mature.

Streaming video is another opportunity to use video lectures. It allows transmitting and viewing video in real time through the Internet. Instead of downloading an entire video file, learners can download small portions of digital video files – the program downloads files in smaller size buffer packets. When appropriate number of buffer packets is reached to begin playing the video, the client's media player displays the packets into one seamless stream. Once a streamed file has been downloaded and viewed, the physical file is no longer present on the user's computer. The technology behind video streaming is described in [31].

Educational providers are considering provision of material also via handheld devices, often called podcasting or vodcasting [31]. Podcasting is the process of capturing an audio event and then posting that digital sound object to a Web site in a data structure called an RSS 2.0 envelope (or "feed"). Using specialized news readers like iPodder or iPodderX, users can subscribe to a Web page containing RSS 2.0 tagged audio files on designated web pages and automatically download these files directly into an audio management program on their personal computer like iTunes, Windows Media Player or MusicMatch. When a user synchronizes their portable audio device with their personal computer the podcasts are automatically transferred to that device to be listened to at the time and location most convenient for the user [38]. Vodcasting – where VOD stands for video-on-demand is almost identical to podcasting. The difference is that the content is video versus audio, and the content is more likely to be played on a laptop than a PMA (personal media assistant) due to their newness and relative expense [38].

Nowadays educators are looking for the best means to help students in their learning. Pedagogically sound video lectures are one of the possible means. Taking advantage of developments in technology combined with appropriate learning theory [32], [31] supports the suggestion that students should be able to achieve higher learning outcomes. The preliminary findings [32] show some significant results that encourage the further study in video lectures.

2.6.2 Delivery methods of e-learning outcomes

Students usually acquire knowledge in unidirection by studying video, reading textbook. Subsequent discussions of problems, solving exercises, case studies, review questions, etc., help the students to understand better what they learned. Electronic media i.e., e-mails, discussion forums, voice mail, are often employed for communication. Homework assignments are normally submitted electronically, e.g., as attachments or by provided link in VLE. When help is needed, lecturers, tutors, fellow students or help desk are available. [30]

2.7 Courseware to support e-learning

Research shows that VLE's are mostly used for delivery of learning materials [40]: PowerPoint slides, lecture notes. Reference [41] describes this as the first and basic stage in the use of e-learning. Teachers use VLEs to provide a web version of their classroom activities. In other words, tutors 'webify' their face-to-face sessions. Unfortunately, the impact of this transfer of the didactic, transmission approach to learning and teaching from face-to-face to web-based instruction is very limited.

According to the model of learning and teaching proposed by Mayes&Fowler [42]the learning with technology involves a cycle of conceptualization, construction and dialogue. In an article written by Mayes & Fowler, Mayes examines how different learning activities support students' understanding of new concepts and the revision of erroneous concepts. This is achieved in three stages, known as the Conceptualization Cycle:

- *Primary* type of courseware. At the conceptualization stage, students are exposed to other people's ideas or concepts (for example in traditional face-to-face sessions or accessing content on the WWW).
- *Secondary* type of courseware. At the construction stage students apply these new concepts in the performance of meaningful tasks.
- *Tertiary* type of courseware. It is only at the dialogue stage, in the performance of tasks in which these new concepts are tested during conversation with tutors and peers, that learning takes place. The feedback provided enables students' erroneous conceptions to be resolved.

Mayes & Fowler framework maps three fundamental stages of learning onto three kinds of courseware. The *primary* courseware has been over-emphasized at the expense of supporting task-based learning and dialogue. As the technology of learning becomes ubiquitous at all levels of education, so it will be seen to be a tool for supporting the kind of tasks that teachers have always encouraged learners to undertake. We can expect a more focused effort to go into the design of task support environments with the *secondary* courseware. The idea of *tertiary* courseware, however, opens up a new kind of thinking about learning technology, and we expect to see many versions of this idea emerge in education. The main message here is that nothing can be as effective as the dialogue between a teacher and a learner. It remains to be seen whether technology can provide a partial substitute for this, in situations where the real thing is not readily available.

2.7.1 Evaluation criterions of courseware

According to the NEEDS (The National Engineering Education Delivery System is a web based digital library of learning resources for engineering education [43]) the definition for engineering courseware is "Engineering courseware is computer-based educational material that can be used to assist engineering students in their learning process". The NEEDS, along with founding sponsor John Wiley & Sons, Inc., developed the PREMIER AWARD to promote successful courseware, as well as provide models of excellence for educators planning to incorporate or develop courseware in the future. The recent study of "Best Practices in the Design, Development and Use of Courseware in Engineering Education" performed by the NEEDS [44] resulted in certain recommendations and conclusions, which we list here:

- Courseware should have a clear statement of and support for appropriate learning objectives and goals.

- The learner should be actively involved in the learning process via interaction with the courseware and other learners.
- Learning should be integrative and transferable.
- Content should be well chosen and structured.
- The courseware should hold the interest of a diversity of learners.
- The learner (user) interface and navigation should make the courseware easy to use.
- Courseware should be used in appropriate instructional settings or learning environments and with appropriate audiences.
- The use of courseware and its impact on learning should be conducted to include appropriate stakeholders and assessment methods.
- The courseware should be technically reliable.

In addition to the specific best practices identified in this paper [44], an examination of the courseware recognized by the Premier Award leads to the following general observations:

- Learning objectives, goals and assessment strategies are critical aspects of good courseware design. The best thing is to embed these features within the software itself.
- Case studies can be effective types of courseware—they can demonstrate real-world problems and situations requiring effective synthesis and analysis.
- Games can be effective in engaging students' attention in courseware and they can be designed to enable the learner to demonstrate his/her understanding of the material.
- Presenting comprehensive content should be accompanied by effective structure, navigation and interactivity.
- Interactive animations and simulations can be important features of courseware—they enable learners to learn in multiple ways by connecting calculations and numbers with physical representations.
- Courseware should be flexible—in the settings, audiences and objectives for which it is used so that it may be easily adopted and adapted by others.

According to implementation method we could classify learning courseware into two groups: a) virtual laboratories, b) remote online laboratories.

2.7.2 Virtual laboratories or simulators

Interaction to software simulators helps students to grasp difficult theoretical concepts or develop specific skills. We could subdivide this kind of software into two groups:

- a) Downloadable stand alone software applications. These should be installed in the student's computer.
- b) WEB based interactive simulators that do not require installation in local computer—they are integrated in internet browser. However, sometimes there are prerequisite requirements which are easy to fulfill: JAVA virtual machine, LabView runtime environment installation. These software components are free and should be installed only once.

Many good examples exist in both groups of software. We can find them in many engineering disciplines, but especially in deeply theoretical disciplines such as digital signal processing (DSP), electronics, microelectronics, and physics. The source [45] lists many good examples as the best practices to follow.

The first group of courseware is easier to develop, but more difficult to maintain and upgrade. The development is done in high level languages MatLab, LabView or Simulink. Good example of such courseware in DSP discipline is SIVA package developed in the University of Texas at Austin [46]. Courseware is free and it is used in 275+ academic, industrial and other sites around the world. The source [46] presents vast collection of up to date courseware for introducing DSP concepts, operations, and algorithms.

The second group of courseware has advantage that it can be accessed using internet browser, thus there is no need to install software locally. This kind of software can be developed using JAVA Applets or Labview remote panels technologies, Macromedia Shockwave and others. Many sophisticated examples exist in different disciplines: JDSP-DSP laboratory on the internet [47], Virtual Oscilloscope developed at Technical University Berlin [48], laboratory incorporating virtual pulse generator and virtual oscilloscope developed at Biomedical engineering institute of Kaunas University of Technology. The later represents the integrated example of primary, secondary and tertiary courseware according to Mayes & Fowler framework. By using this labwork the student is able to develop the skills required to efficiently control oscilloscope in order to measure different parameters of pulse signals. The software provides online feedback to the student if his just measured parameter is within error limits.

2.7.3 Remote interactive laboratories

Experiments allow a student to compare reality with simulations, collaborate with each other, and give them the opportunity to follow their curiosity. However, many science and engineering classes do not include a lab component because of significant expense and space considerations. Internet made feasible new kind of laboratories- remote laboratories with real interactive experiments by using internet connected laboratory equipment: measurement devices and devices under investigation. Several factors inspired such laboratories:

- The potential to share the rare and expensive equipment;
- The potential to share geographically scattered equipment;
- Possibility to access the equipment at any time any place.
- Possibility for cooperation between academic and industrial researchers.

Many attempts were made to develop remote laboratories in different disciplines: electronics [49], microelectronics [50], systems and control [51], [52], photonics [53], remote experiments in image processing [54], [55].

However, such systems are difficult to build. They require a lot of recourses: human (pedagogy representatives, software and hardware developers), equipment, finances. Interesting systems are developed in Massachusetts Institute of Technology and they are linked with` the project iLabs [56]. This project is sponsored by Microsoft Research. Online laboratories (“iLabs”) are experimental set ups that can be accessed through the Internet from a regular web browser. iLab teams have created remote laboratories at MIT in microelectronics, chemical engineering, polymer crystallization, structural engineering and signal processing as case studies for understanding the complex requirements of operating remote lab experiments and scaling their use to large groups of students at MIT and around

the world. The project iLabs developed a typology of internet accessible labs [57]. They distinguished three types of laboratory experiments:

- *The Batched Experiment.* The lab session consists of submitting an experiment protocol, executing the experiment, and then retrieving and analyzing the results.
- *The Sensor Experiment.* In this experiment student usually can not specify any parameters although he may be able to select the particular sensor data that he wishes to receive. Running the experiment consists of subscribing to real time sensor data.
- *The Interactive Experiment.* In an interactive experiment, the student typically sets a series of parameters, initiates the experiment, and then monitors the experiment's course, changing control parameters as necessary.

The study [58] presents one of the iLab projects - web-based laboratory for students in courses on Feedback Systems.

The remote lab for learning ultrasound medical diagnostics was developed at Biomedical engineering institute of Kaunas University of Technology [59]. The remotely accessible software and hardware is integrated with the content in the Moodle VLE for preliminary preparation and assessment. Thus it can be considered as an example of tertiary courseware according to Mayes & Fowler.

3 Conclusions and recommendations

- E-learning material should be based on learning theories. Behaviorist strategies can be used to teach the facts (what); cognitivist strategies to teach the principles and processes (how); and constructivist strategies to teach the real-life and personal applications and contextual learning;
- Should be a shift toward constructive learning, in which the opportunity is given to learners to construct their own meaning from the information presented during the online sessions. The use of learning objects to promote flexibility and reuse of online materials to meet the needs of individual learners should become common;
- Online learning materials should be designed in small coherent segments, so that they can be redesigned for different learners and different contexts;
- Learning material must account different learning styles (visual, verbal, kinesthetic). Thus it must be prepared using multimedia tools and include visual information (slides, video, animation) and audio information. The learners should have possibility to choose what mode of information they would like to use.
- VLE should provide these features: delivery and management of course content, access control, administration, time-tabling facilities, assessment, communication on various levels (one to one, one to many, synchronous and asynchronous).
- Moodle is chosen as VLE. It will also serve as a link to other VLEs (e.g. Web CT, BlackBoard) used by other institutions.
- Student-centered learning activities should be encouraged.
- In order to fulfill student centeredness requirement, e-learning environment must include the courseware in the form of online demonstrations, interactive simulations or remotely controlled labs. It is desirable that courseware would have all three attributes of "good practice" courseware: primary (exposition of concepts), secondary (application of concepts to solve the task) and tertiary (dialogue and assessment).

- Community-centered learning activities should be encouraged. The novel scenario in problem based learning, where group work with changing roles (“problem owners” and “problem solvers”) could be implemented and evaluated.
- Student’s activity should be tracked and assessed. Formative assessment is preferred in e-learning environments.
- Several licensing schemes of e-learning materials exist. Creative Commons Attribution license seems to be most popular.

The key message of one recently held conference in UK [57]: “educational institutions which do not take e-learning seriously (and by extension, VLEs, or other learning platforms) will, in the long term, lose out to those institutions which have made a commitment, and which have managed to move from the fringes, into the mainstream”.

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5 Appendix

A2 Examples of online e-courses in Biomedical Engineering

The aim of this appendix is to review how e-material can be presented. Several examples are listed where biomedical engineering related modules have been taught at different levels:

Bioelectromagnetism in EVICAB. Online book and video material.	http://butler.cc.tut.fi/~malmivuo/bem/bembook/index.htm
University of Malaysia Biomedical Engineering. The course content is available on-line and prepared as PDF files.	http://biomed.um.edu.my/notes/biokimia
The course of electronics is prepared as a Web page where clear definition, module prerequisites, and expected outcomes are defined.	http://www.free-ed.net/sweethaven/ModElec/acee/aceeTOC.asp
Massachusetts Institute of Technology (MITOPENCOURSEWARE) provides a wide choice of open courses, including biomedical engineering. Each course module contains syllabus, lecture notes, assignments, discussion group and other related features (e.g. videos, calendar). Lecture material is available as PDF, video or audio files.	http://ocw.mit.edu/OcwWeb/Biological-Engineering/20-010JSpring-2006/LectureNotes/index.htm
The developed simulator is a cost-effective means of gaining both practical and theoretical expertise in assessing the health of a carotid artery via Doppler Ultrasound System.	Samira Hirji, Real-Time and Interactive Virtual Doppler Ultrasound, Master thesis of Engineering Science, Faculty of Engineering, Biomedical Engineering Graduate Program, The University of Western Ontario, Canada; February 2006
An example of one such study yielded positive results, and was performed on the UltraSim (MedSim, Fort Lauderdale, Florida, USA) simulator, where radiology residents were evaluated to assess the effectiveness of the simulator as a means to measure the residents' expertise.	Monsky, W.L., Levine, D., Mehta, T.S., Kane, R.A., Ziv, A., Kennedy, B. And Nisenbaum, H., Using a sonographic simulator to assess residents before overnight call, <i>AJR Am J Roentgenol</i> , 178 (2002) 35-9.
The major effect of remote access laboratory classes using the weekly exercise regime is a large increase in the time that students spend operating equipment, albeit mostly remotely. The	James TREVELYAN, Lessons learned from 10 years experience with remote laboratories, International Conference on Engineering Education and Research "Progress Through Partnership" © 2004 VŠB-TUO, Ostrava, ISSN 1562-3580.

<p>significant gain in student operating time achievable with remote labs, therefore, is likely to confer significant increase in practice time and hence contribution to skill development.</p>	
<p>Three examples of remote labs for electronics.</p>	<ul style="list-style-type: none"> • Chirico, M.; Scapolla, A.M.; Bagnasco, A. “A new and open model to share laboratories on the Internet” Instrumentation and Measurement, IEEE Transactions on Volume 54, Issue 3, June 2005 Page(s):1111 – 1117 • D. Muller, J. M. Ferreira, “Online labs and the MARVEL experience”, Intern. J. Online Eng., vol. 1, no. 1, 2005. http://www.i-joe.org/ojs/include/getdoc.php?id=41&article=4&mode=pdf • S. Grober, M. Vetter, B. Eckert and H.-J. Jodl, “Experimenting from a distance—remotely controlled laboratory (RCL)”, Eur. J. Phys., vol. 28, pp. S127-S141, 2007.
<p>One example of remote labs for microelectronics.</p>	<p>Bertrand, Y.; Flottes, M.-L.; Azais, F.; Bernard, S.; Latorre, L.; Lorival, R.; A remote access to engineering test facilities for the distant education of European microelectronics students Frontiers in Education, 2002. FIE 2002. 32nd Annual Volume 1, 6-9 Nov. 2002 Page(s):T2E-24 - T2E-29 vol.1</p>
<p>Two example of remote labs for systems and control.</p>	<ul style="list-style-type: none"> • Sanchez, J.; Dormido, S.; Pastor, R.; Morilla, F “A Java/Matlab-based environment for remote control system laboratories: illustrated with an inverted pendulum” Education, IEEE Transactions on Volume 47, Issue 3, Aug. 2004 Page(s):321 – 329 • Magnetic levitation hardware-in-the-loop and MATLAB-based experiments for reinforcement of neural network control concepts Shiakolas, P.S.; Van Schenck, S.R.; Piyabongkarn, D.; Frangeskou, I.; Education, IEEE Transactions on Volume 47, Issue 1, Feb. 2004 Page(s):33 – 41
<p>Example of remote labs for photonics.</p>	<p>Gao-Wei Chang; Zong-Mu Yeh; Hsiu-Ming Chang; Shih-Yao Pan “Teaching photonics laboratory using remote-control web technologies”; Education, IEEE Transactions on Volume 48, Issue 4, Nov. 2005 Page(s):642 – 651</p>
<p>Implementation of remote labs for Ultrasound medical diagnostics.</p>	<ul style="list-style-type: none"> • R. C. Almgren, J. A. Cahow, “Evolving Technologies and Trends for Innovative Online

	<p>Delivery of Engineering Curriculum”, Intern. J. Online Eng., vol. 1, no. 1, 2005. http://www.i-joe.org/ojs/include/getdoc.php?id=39&article=5&mode=pdf</p> <ul style="list-style-type: none"> • J. Bourne, D. Harris, F. Mayadas, “Online Engineering Education: Learning Anywhere, Anytime”, J. of Eng. Edu., vol. 94, no. 1, pp. 131–146, January 2005. • J. Garcia-Zubia, D. Lopez-de-Ipina, U. Hernandez, P. Orduna, I. Trueba, “An Approach for WebLabs Analysis”, Intern. J. Online Eng., vol. 3, no. 2, 2007. http://www.i-joe.org/ojs/include/getdoc.php?id=374&article=119&mode=pdf
Experience in remote ultrasound experiments.	H. Ewald, G.S. Page, Performing Experiments by Remote Control Using the Internet, Global J. of Engng. Educ., vol. 4, no. 3, pp. 287-292, 2000.
Less than 10 % of found 120 remote labs projects world-wide were dealing other disciplines that engineering and physics.	S. Grober, M. Vetter, B. Eckert and H.-J. Jodl, “Experimenting from a distance—remotely controlled laboratory (RCL)”, Eur. J. Phys., vol. 28, pp. S127-S141, 2007.
Experimenting from a distance—remotely controlled laboratory	Operate an optical analog of a computer tomography and learn how it works! Location: TU Kaiserslautern, Germany; http://rcl.physik.uni-kl.de
Virtual Clinical Engineering: From Biomedical Basics to Practical Applications	http://www.clevemed.com/pdfs/Virtual%20Clinical%20Engineering.pdf
Hands-on learning in biomedical signal processing. The interactive exercises, consist of a Web-based tutorial centered on a simulation of Fourier spectral analysis .The simulation allows students to select key parameters and perform spectral analysis of cosine, ECG, and speech signals.	http://web.mit.edu/6.555/www/matweb/demo.html
A Web-based teaching device was constructed to deliver information on fundamentals of ultrasound imaging to approximately one half the students in an undergraduate medical imaging course, while the remaining students were taught the same material via traditional lectures and typed notes	http://www.bme.vanderbilt.edu/bme258/ultrasound/tutorial/tutorial.html

<p>Demonstration Materials from Vanderbilt-Nortwestern-Texas-Harvard MIT Engineering Reserch Center for Biomedical Engineering Educational Technologies.</p>	<p>http://www.vanth.org/mmedia/nsfweb02/vwr/demos.htm</p>
<p>Interactive Web-based Instructional Modules concerning Human Joint Mechanics using the Legacy Cycle.</p>	<p>Freeman, R.A. and Crown, S.W. (2001), Proceedings of the American Society for Engineering Education Session 1609: 16 pages. CD-ROM. Mira Digital Publishing, Inc. http://www.vanth.org/docs/014_2001.pdf</p>
<p>The interactive demonstration is implemented using the MATLAB /Web Server. It performs spectral analysis of cosine, ECG, and speech signals.</p>	<p>http://web.mit.edu/6.555/www/matweb/demo.html</p>
<p>Duke University. Virtual Imaging Laboratory.</p>	<p>http://dukemil.egr.duke.edu/</p>
<p>University of California, Berkeley, Webcast courses/ audio/MP3</p>	<p>http://webcast.berkeley.edu/course_details.php?seriesid=1906978483</p>
<p>Project Videlectures.NET, 2273 video lectures</p>	<p>http://videlectures.net/</p>