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Towards Equal Opportunities in Computer Engineering Education: Design, Development and Evaluation of Video-based e-Lectures*

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Innovative instructional technologies not only improve standard, classical learning methods for users but also provide learner centered educational tools that make it possible for people with special needs to benefit from the same courses as learners without disabilities. This paper describes some of the current systems that are available and details a closer study made of one of those: the Video-based e-Lectures for All Participants (VeLAP) system. The study was carried out during sample lectures in engineering using N = 75 students (16 women and 59 men) from technology oriented faculties. The results were evaluated according to their pedagogical effectiveness, including analysis of covariance (ANCOVA) comparison tests. Whilst the emphasis was placed on the applicability of the educational methods for assisting the needs of a special target group, people with audio and/or visual disabilities, the usability of the system for all users, including the teaching staff, was tested according to the standardized Software Usability Measurement Inventory (SUMI). Our findings indicated areas of possible improvement and highlighted the web controls that required adjustments to make the system more usable.

Keywords: web-based education; video streaming technology; people with special needs; evaluation

INTRODUCTION

LEARNER-CENTERED EDUCATIONAL TOOLS can enlarge the boundaries of the classical engineering classroom setting as well as enhance interdisciplinary learning, where learners solve problems and make discoveries in exploratory ways [16–18]. One such learning tool is the emerging video lecture streaming technology [10]. However, the success of these tools is highly dependent on the right instructional design [2, 4, 7]. Successful situational learning with continuous media interaction requires both sophisticated technological and appropriate psychological concepts to be in place to enable learners—independent of their age and abilities—to easily access the material, which must be properly adapted to the actual needs, demands, requirements and previous knowledge of the learners [1, 5].

Carefully planned material can enable the broadening of knowledge and a deeper understanding of the material. However, the production of live streaming videos and videos on-demand is a complex and particularly time consuming process. Consequently, simple usage and good usability in creating material, recording and maintenance of the lectures is a basic requirement. Most of all, with the application of these technologies, we can assist learners with special needs in their learning process because such technology can offset their difficulties and offer them an equality of opportunity unmatched by standard classroom methods.

For specially targeted groups, the main difficulties arise when delivering the learning material to students with special needs. People with special needs, such as the deaf and hard of hearing or the blind and weak-sighted, need to be treated as students without disabilities. They require adapted and efficacious computer-based technologies that employ the World Wide Web and the Internet [34]. For this group of users, the most common inhibiter is the high-level of difficulty that they experience when participating in the traditional form of education. In previous European projects, such as SMILE [35], EVIDENT [36] and VISIOCOM [37], the special requirements for deaf people were addressed. The areas of difficulty for deaf people are their lack of writing and reading abilities. This is because the language that they previously used was sign language. Consequently, teachers have to face the fact that deaf people may have a low level of literacy and a poor understanding of wording.

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For the reasons mentioned above, we designed, developed and evaluated a robust lecture web cast system: Video-based e-Lectures for All Participants (VeLAP). Its main features include a mobile video recording system with user friendly, remote recording functionalities; the ability to fully and automatically record lectures and simultaneously include all additional materials (presentation slides, subtitles, table of contents) for live and on-demand web presentations; live screen capturing; accessibility issues for people with special needs; additional sign language video and subtitles (for deaf and hard of hearing learners); audio subtitles for blind users as well as text enlargements capabilities, background/foreground color corrections and video navigation for weak-sighted and color-blind users, as well as the ability to customize user interfaces.

BACKGROUND AND RELATED WORK

The increasingly popular User Centered Design (UCD) approach [19–22] has grown in parallel with the focus on the end-user. Ideally, UCD is based on the end-user's abilities and needs, context, work and tasks. The normative perspective of UCD is that there is no average end-user and, consequently, the design should be targeted towards specific end-user groups [23]. Similar to this approach, Learner-Centered Design (LCD) evolved from theories of constructivism [24–26] and Problem-Based Learning [27–30]. The central idea of LCD is to involve the learners in the learning activity and focus education on realistic, intrinsically motivating problems [31]. In general, learner-centered designs must follow three principles:

1. *Enabling* the learner's understanding (e.g. strengthened through structuring, coaching, critiquing etc.)
2. *Sustaining* motivation [32] (e.g. through low-overhead and immediate successes or putting learning into the context of doing)
3. *Offering* of a diversity of learning resources (e.g. using different media and different tools).

Soloway *et al.* [33] proposed that a LCD process must focus on three things:

1. the *tasks* that learners must undertake;
2. the *tools* that they can use to deal with those tasks;
3. the *interfaces* for those tools.

There are several research-based e-learning systems currently available. Pyramidia [9] is a straightforward and easy-to-use software tool that was developed to improve educational effectiveness by recording lectures. The tool is composed of two applications: the Producer for creating lectures and the Player for experiencing them. The Producer has been designed to record from two separate video sources and one audio source. As a primary video source, everything that happens on the lecturer's screen is captured (PowerPoint presentation, Internet browsing, etc). It is advisable to set the secondary source to record the lecturer speaking, in order to emulate the classroom experience. Additional information is provided by the PowerPoint parsing system, which is basically a PowerPoint plug-in (a toolbar), allowing supplemental content (indices, questions and links) to be added to slides, while composing the presentation. These can be added before and/or after the lecture is recorded. At the end of the recording, a .lec file is created and stored locally. To view the lectures, students need the Player application, which consists of the usual functions that are normally found on existing media players but also includes some enrichment elements such as quizzes, the ability to add bookmarks to remember specific locations, and the ability to set the visibility of context sensitive questions and filter the lecturer's information.

The EyA ('Enhance your Audience') system archives and shares scientific lectures carried out using either modern presentations (PPT, PDF, animations, etc.) or the traditional chalkboard lectures [8]. This system records video/audio on a local computer over a webcam and USB microphone fixed on the wall. Every 15 seconds, photos are taken with a digital camera and sent to the computer via USB. After 1 hour, all photos with the movie and all information about the synchronization are transferred through the network to a dedicated server. The QuickTime synchronization is processed immediately afterwards and automatically published on the web.

The InterLabs Web-lecturing system [10] is a tool for creating material and recording lectures. The creators claim that their tool is based on several founding principles, such as innovative software, streaming technologies, communication technologies, modularity of learning content, multiple teaching styles, multiple delivery modes and equivalence in quality of the delivered learning content. Lectures are created using the Creator tool, which is capable of capturing video and audio from external resources, on-the-fly video encoding, the synchronization of various types of media, the compilation of output files for various bandwidths, the ability to add available Web-based communication and collaboration tools, the creation of a webified graphical user interface, the ability to navigate through slides, and the capability of Web publishing the developed streaming media-based learning modules on a streaming server. All these tasks are performed in one uninterrupted session.

The VeLAP system shares many similarities with the research-based systems. One key feature, however, that they do not support is live streaming; therefore lectures can be experienced only in an on-demand way. On the other hand, some of the existing commercial webcast systems on the market, such as AnyStream, Wimba, GoodMood,

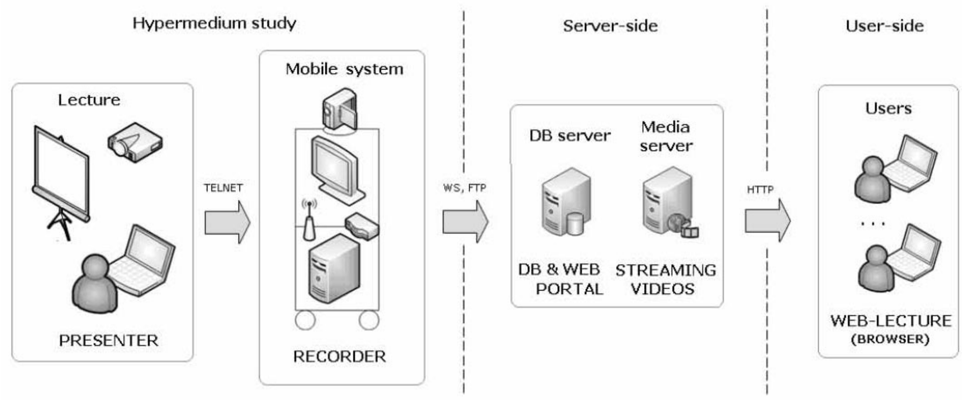

Fig. 1. The VeLAP lecturing process.

and Virage do enable the recording of live lectures. These commercial products deliver basically the same learning modules to the users: video and audio-recordings of the lecture, a slideshow that is synchronized with the video, time-based and/or slide-based navigational elements, and interactive modules such as chat, questions, and polls. However, these systems do not fully consider the requirements of people with disabilities. In rare cases (Wimba, AnyStream), they provide a video interpreter for sign language and textual subtitles, which is suitable for deaf and hard of hearing students, but completely fail to offer support for blind and weak-sighted users. In contrast to these systems, VeLAP provides the additional media that are required by persons with disabilities concurrently with the traditional webcast elements (video, audio, table of content and screen capturing).

THE VELAP SYSTEM

Innovation

The main concept behind the VeLAP system is supported /maintained by a proposal of the European Broadcasting Union (EBU) that precisely defines how people with disabilities should be accommodated [11]. However, the EBU recommendations are defined mainly for the broadcasting area. We considered these recommendations and implemented several in the development phase. In addition to the traditional web cast elements (video and audio presentations, table of contents and screen capturing), we introduced elements that are required by people with disabilities. These include videos of sign language interpreters for the deaf, textual subtitles for the deaf and hard of hearing, and audio subtitles for blind and weak-sighted users, which can either be recorded simultaneously during a live presentation or added later as required. Furthermore, in doing so, the need to develop various applications for specific groups of users was eliminated; for instance, the visually designed e-learning applications for deaf and hard of hearing users includes textual translations into sign languages and the auditable designed applications needed by the blind and weak-sighted users. In addition, accessible Web-lectures were planned and designed according to WCAG guidelines [12].

The lecturing process

The VeLAP system incorporates the basic Web-casting concept [14]; however the performance efficiency depends on the equipment employed and on the end user's access to high-speed Internet as web-casting requirements are demanding when it comes to the quality of the infrastructure. For instance, deaf people need at least CIF (352*288) format video. Also, a minimum of 300 kbps should be used for the encoding process, in order to achieve a frequency of 15 fps for the streaming video, ensuring smooth enough hand movement for the sign language [13].

The VeLAP lecturing process is shown in Fig. 1.

The Hypermedia study is a new learning environment with interactive streaming video technology that includes at least one mobile-recording system with video and audio equipment for producing lectures. There are two essential applications employed in the VeLAP system: the Recorder and the Presenter, which are both Windows-based .NET applications. The decision to use the Microsoft Windows platform was made because of its daily use in our institutions by students and professors. Other reasons were the technical aspects: Windows Media Server provides powerful streaming technologies and we had specific expertise in programming languages using the .NET framework for implementing the web and desktop applications. The Recorder application is installed on the mobile system. Its functions include lecture initialization, creating and managing publishing points on media server, and encoding and streaming the video from the digital camera. Web services aid the transmission of the information. The work-flow of the Recorder application is described in Fig. 2.

The Presenter application initially enables a selection between several modes of media types

Fig. 2. Recorder's work-flow.

(Fig. 3). This includes audio, video and screen capturing functionalities. It is also capable of remotely controlling the digital camera, which is mounted on a PTZ (pan-tilt-zoom) holder, sending recording commands to the mobile system over a telnet protocol and managing interactive questions posted by the Web-lecture participants. This is possible with a pop-up dialog, containing the questions posted.

In a basic scenario, the lecturer uses one mobile system, one presentation computer and a projector. A four step wizard ensures the simplicity of the lecturer's presentation work-flow. Recording lectures works on the basis of merging separated media modules into one interactive live Web-lecture. Additional videos, such as subtitles, videos of sign language interpreters and audio subtitles can be recorded simultaneously as alternative streams. A qualified person is needed to describe the lectures for the audio subtitles and a fast typist is required to use the Subtitles application, intended only for live streaming mode, to provide textual subtitles.

Web-lecture

An enriched Web-lecture, shown in Fig. 2, is the result of the VeLAP lecturing process. With the use of Microsoft's COM (Component Object Model) technology the PowerPoint slides convert into HTML during the presentation process and the synchronization with the video is done automatically. Media switches can switch between different media types; in our case, from original video (primary stream) to the video of the sign language interpreter (secondary stream) or to the presentation slides. In this way the user can control the screen layout by determining the most suitable viewing layout. The third switch pops up a new window with alternative streams (for instance, a sign language interpreter). This can be placed in any part of the screen or even on a second monitor using a full-screen view. The questions module increases the interactive presence.

MATERIAL AND METHOD

Preparation

In order to demonstrate and evaluate the usability of the innovative instructional technologies for all users, including people with special needs, we conducted four studies.

1. In order to evaluate and compare their pedagogical effectiveness, comparison tests between traditional learning and on-line learning were conducted using the assessment of preliminary and gained knowledge with an experimental

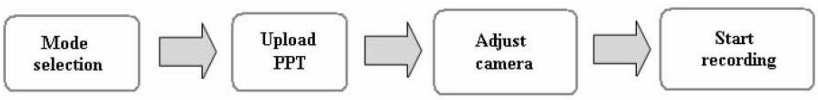

Fig. 3. Presenter's work-flow.

Fig. 4. VeLAP Web-lecture.

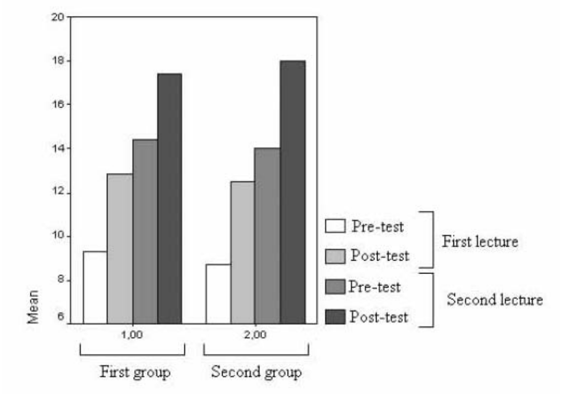

Fig. 5. Knowledge progress.

Pre-Test/Post-Test experimental control group design, running ANCOVA.

2. Application of the Learning Study and Strategies Inventory (LASSI), which is a 10-scale, 80-item assessment of students' awareness about, and use of, learning and study strategies related to skill, willpower/motivation and self-regulation components of strategic learning. The focus is on both covert and overt thoughts, behaviors, attitudes and beliefs that relate to successful learning and that can be altered through educational instrumentality /involvement. Research has repeatedly demonstrated that these factors contribute significantly to learning success [6].
3. Testing the usability of the system, according to standardized SUMI (Software Usability Measurement Inventory) evaluation, which shows the Efficiency, Effect, Helpfulness, Control and Learnability of the developed user interfaces [3].
4. Question-thinking protocol including people with special needs.

Procedure

The study was carried out with two 10-minute sample lectures from the field of engineering education, where the learning process demands the use of multiple-sensory aspects. The first lecture was entitled 'Basic in Control System', and the second 'Security of Computer Systems'. We carefully eliminated the theme's influence on the testing results by controlled settings. $N = 75$ students from technical-oriented faculties took part in our studies. There were 16 women and 59 men. The first group, consisting of 39 students of electrical engineering, had participated in face-to-face lectures. At the same time, the lectures were recorded with our VeLAP system. The project holder initially introduced the aim of the project and introduced both lecturers who held 10-minute presentations with PowerPoint slides. All students were required to complete the LASSI questionnaire. Before and after the lecture, they completed a knowledge assessment questionnaire containing 15 questions on the first lecture and 20 questions on the second lecture. Although the questions remained the same, their order of presentation was altered. The second group, consisting of 36 multimedia communications students, had participated in both video-on-demand lectures, each person on a computer with headphones. The VeLAP Web-lecture was automatically generated during the face-to-face group, and the subtitles were added later. The study procedure in the second group remained the same as in the first group (Table 1); students in the second group had to complete the SUMI questionnaire with 50 additional standardized questions.

RESULTS AND DISCUSSION

Our results revealed that both groups, face-to-face and video on-demand, had positive knowledge growth regarding prior knowledge (Fig. 3). It was obvious that the knowledge increase in the face-to-face group was different (3.51—first lecture and 3.02—second lecture) from the video-on-demand group, where all increases were almost the same (3.75—first lecture and 4.00—second lecture). ANCOVA showed that there is no distinction between the groups in the first lecture, whilst in the second lecture there is a significant difference ($p < 0.05$). This was in favor of the second group, which had gained a higher increase in knowledge after the second lecture.

After calculating five SUMI usability subscales, all scales showed values above the standard, 50, for state of the art commercial software. The global scale showed a value of 57 and the best value was learnability, with 60. The lowest scale was control with 54. In this way, the equilibrium of all usability scales in the system was indicated. The SUMI result is depicted in Fig. 6.

Table 1. Implementation of the study procedure

Study procedure	**Face-to-face lectures (first group)**	**Video-on-demand lectures (second group)**
Introduction and study description	•	•
LASSI questionnaire	•	•
Knowledge Pre-test assessment	•	•
10-minute lecture	•	•
15-minute topic discussion	•	
15-minute on-line knowledge immersing		•
Knowledge post-test assessment	•	•
SUMI questionnaire		•

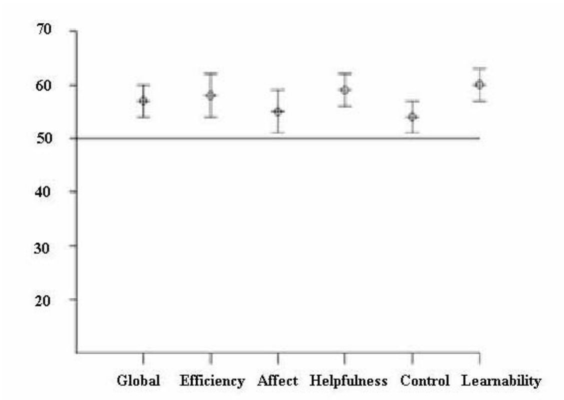

Fig. 6. SUMI result.

USABILITY EVALUATION WITH DEAF AND BLIND USERS

Participants

The end users who took part in this study were deaf and hard of hearing people from the Association of Hard of Hearing, Slovenia. The blind test users were from the Institution of Blind and Weak-Sighted Youth in Slovenia. Altogether there were 19 subjects with special needs. In the introduction phase, we collected information about their gender, age and browsing experience on the Internet.

There were 11 deaf and 2 severely hard of hearing subjects in the first experiment, with 23% female and 77% male. Subjects ranged from 34 to 72 years old, with a mean age of 52. Regarding the Internet browsing experience, 61% subjects had no experience at all, while 8% had browsed only a couple of times and 31% had excellent skills.

The second experiment included 7 blind subjects from secondary school with average browsing experience. There were 3 female and 4 male subjects. The age ranged from 11 to 19 years; the mean age was 15.

Instrumentation

The testing environment for both experiments included a desktop computer with a broadband Internet connection. Blind subjects additionally used a Braille keyboard and a screen reading application, JAWS version 9.0. Subjects used Internet Explorer® 6 for browsing the Internet. During the evaluation process, audio recordings for taping the discussion with the subjects were used.

Procedure

There were two experiments involving people with special needs. The first experiment included the deaf and hard of hearing users and the second included only the blind subjects. As the main purpose of the Web portal is to deliver web lectures, we tested basic tasks in on-line participating for both groups. Users were asked to complete six tasks that were read out to them one at a time.

1. Log into the user account.
2. Go to the profile settings.
3. Find a specific lecture and click the link.
4. Change the video in Window 1.
5. Close the lecture.
6. Logout.

In both experiments, we used the same testing method, the question-asking protocol [38] that prompts users by questioning them about the product. We selected this method over the thinking aloud protocol [39] because blind people are unable to listen to screen reading applications and verbalize their thoughts at the same time, as discussed in [40]. For deaf people, a modified thinking aloud protocol, called the gestural think-aloud protocol, is more suitable as proposed by [41].

The main focus of the first experiment with deaf and hard of hearing subjects was the Web lecture experience. Therefore, participating meant experiencing the same web lecture for 30 seconds in four different modes as depicted in Table 2.

During each mode, the evaluator observed the subject's reactions; at the end, questions about the graphical user interface were asked. The communication among evaluator subjects was facilitated by a sign language interpreter.

The second experiment focused on accessibility features for blind users by using the JAWS application. The use of the hyperlinks in the JAWS application is usually managed with a list of hyperlinks on the web site. This is accomplished with a combination of hot keys. We tested this feature to find out whether the subjects could find all the hyperlinks needed for performing the tasks. Furthermore, we tested the usability of navigation functionalities inside the media player window. The last test for the blind subjects was the examination of the readability of the presentation slides and an investigation of WAI / WCAG conformity.

Results and discussion

The experiment with the deaf and hard of hearing subjects revealed that 69% needed help

Table 2. Web lecture GUI modes for the deaf

	Window 1	Window 2	Window 3 (pop-up)
Mode 1	Lecturer	PPT slides	Nothing
Mode 2	Lecturer	Sign language interpreter	Nothing
Mode 3	Sign language interpreter	PPT slides	Nothing
Mode 4	Lecturer	PPT slides	Sign language interpreter

when performing tasks, basically due to their lack of browsing experience. They received additional instructions from the evaluator; specifically, assistance was given in completing the task. It was evident that 77% of the subjects had selected mode 3 as their favorite, while 15% preferred the first mode and only one subject chose the second mode. From this, we conclude that deaf people do not prefer two different videos, streaming simultaneously (one video of a lecturer and one of a sign language interpreter).

Our tests with deaf subjects also confirmed that the most appropriate configuration for video subtitling was enabled in mode 3. All subjects agreed that the subtitles had to be below the video of the sign language interpreter, in comparison with mode 1, where all the subjects were distracted by the media player's integrated navigation bar situated between the video and subtitles.

In the second experiment, all blind subjects were given a Braille keyboard and the JAWS application for performing the tasks. Based on the results of our previous experiment in the implementation phase of the system VeLAP, where two blind users tested the web portal, the navigation of the audio streams needed to be improved. We implemented two additional hyperlinks (start reading and stop reading) to make the reading of presentation slides easier to control. Afterwards, the user can start the video and hear the lecturer and read the presentation slides from the beginning. We had to adjust the type of web controls. Hyperlinks and shortcuts for visually impaired people were therefore installed in place of the web button controls. Moreover, labels were also replaced by hyperlinks to enable easier work-flow over the page. For instance, if a hyperlink was selected, the focus was set to the appropriate web control, since the JAWS application reads active controls.

All the subjects in the present experiment were able to control the videos with the newly incorporated functionality. However, all the subjects failed to select different videos. This was because of the drop-down lists, which the JAWS application did not recognize.

Our results revealed that the web portal is suitable for people with special needs at the current stage. Nevertheless there were some issues and challenges.

- Requirements for switching media windows are different for deaf and blind users.
- The video control bar for deaf users should be above the video window.
- Deaf users prefer one video for a sign language interpreter without the lecturer.

CONCLUSIONS

The most significant feature of the VeLAP system is definitely its simple and automated process in creating and delivering enriched Web lectures based on streaming technology. According to our empirical findings, and according to VAK [16] styles, this feature plays an important role for visually oriented people. We kept in mind user-friendliness and simplicity when designing the system graphical user interface; therefore the graphical user interface was designed as a wizard work-flow to simplify the lecturing process. More than two live video streams can easily be combined, and the preparation required for recording lectures consists of a relatively simple set of operations; the whole procedure for recording and preparation can be completed in a few minutes, including system initialization, connection establishment, and lecture preparation. Furthermore, the VeLAP system is especially designed to accommodate the needs of a special targeted group of users with special needs (blind, weak-sighted, deaf and hard of hearing subjects). Accessibility was determined by testing the system with hearing and visually impaired users, where some issues regarding visually impaired users were addressed.

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