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Development and evaluation of an e-learning course for deaf and hard of hearing based on the advanced Adapted Pedagogical Index method

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Web-based and adapted e-learning materials provide alternative methods of learning to those used in a traditional classroom. Within the study described in this article, deaf and hard of hearing people used an adaptive e-learning environment to improve their computer literacy. This environment included streaming video with sign language interpreter video and subtitles. The courses were based on the learning management system Moodle, which also includes sign language streaming videos and subtitles. A different approach is required when adapting e-learning courses for the deaf and hard of hearing: new guidelines must be developed concerning the loading and display of video material. This is shown in the example of the e-learning course, ECDL (European Computer Driving Licence). The usability of the e-learning course is analyzed and confirmed using two methods: first, the Software Usability Measurement Inventory (SUMI) evaluation method, and second, the Adapted Pedagogical Index (AdaPI), which was developed as part of this study, and gives an index to measure the pedagogical effectiveness of e-learning courses adapted for people with disabilities. With 116 participants, of whom 22 are deaf or hard of hearing, the e-learning course for the target group has been found suitable and appropriate according to both evaluation methods.

Keywords: distance learning; deaf education; sign language; video streaming; web-based education; learning management system; usability; pedagogical effectiveness

Introduction and motivation for study

The need for technology-enhanced learning

In all application areas, there has been tremendous progress in educational technologies and the influence of these new technologies is enormous. It must not be forgotten that learning is both a basic cognitive and social process (Holzinger, 2000) and that education *cannot* and *should not* be replaced with technology (Clark, 1994; Kozma, 1993).

E-learning is considered particularly important for users with disabilities and it generally encompasses learning with the help of technology. Users become familiar

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with computers, the Internet, broadcasting technologies (radio and television) and communication services for gathering and transmitting information related to education (Sandars & Morrison, 2007). However, even though there are many initiatives worldwide for people with disabilities, there is still a lack of research, especially concerning the usability of these methods (Brown et al., 2002; Williams, Jamali, & Nicholas, 2006). Studies have shown that certain aspects of the learning process can be carried out more easily and more efficiently when they are supported by e-learning (Begoray, 1990; Holzinger, Kickmeier-Rust, Wassertheurer, & Hessinger, 2009; Rogers, 2002).

Although e-learning continues to grow in both presence and importance, some researchers have reported a significant number of e-learner dropouts (Mungania, 2003; Tyler-Smith, 2006). In the year 2000, on the basis of an analysis of research results, Sarah Carr estimated the dropout rate to be 10–20% higher for e-learning compared to conventional learning (Carr, 2000). For example, Theofanos and Redish (2005) confirmed that in order to truly meet the needs of all users, it is not enough to have guidelines that are based on technology. The results do show that properly designed technology-assisted learning is significantly more effective than conventional face-to-face learning.

Related work on technology-enhanced learning for the deaf and hard of hearing

The evidence of the efficiency of e-learning leads us to raise the question as to whether e-learning can also be successfully used to educate people with disabilities. Research done by Yang, Lay, Liou, Tsao and Lin (2007) showed that an e-learning system, specifically the computer-aided music-learning system (CAMLS), could be used by hard of hearing people who, until then, did not have an appropriate computer-assisted tool to help them recognize pitch and thus melody. The results confirmed that CAMLS did help hard of hearing students to learn music more efficiently, enhancing students' interest and willingness to devote more time to music.

Even today, the majority of deaf and hard of hearing people still show worse reading/writing and mathematical abilities when compared to hearing people, although their mental abilities are generally at the same level (Drigas & Kouremenos, 2005). Studies conducted on the reading ability of 16-year-old deaf children showed that around 50% of the children were illiterate, 22% of them demonstrated a reading level equivalent to that of a 10-year-old hearing child, and only 2.5% of them demonstrated a literacy level appropriate for their age (Smith & Mayes, 1996). Hanson (2007) reported that profoundly deaf people might have difficulty in acquiring mastery of the spoken language and experience reading difficulties. Therefore, designers who wish to take into consideration the needs of deaf and hard of hearing people as a target group face additional requirements.

One solution to this problem could lie with video technology, as well as understandable and accessible user interfaces, including video and subtitles similar to what was developed for the SignOn project (Hilzensauer, 2006), AILB project (Straetz et al., 2004), ECDL Barrierefrei project (Carpenter, Dolan, Leahy, & Sherwood-Smith, 2000), SMILE (Kronreif et al., 2000), BITEMA – Bilingual Teaching Material For The Deaf by Means of Information and Communication Technology (Debevc, Zorič-Venuti, & Peljhan, 2003), DELFE – Distance and Life Long Training for the Deaf people in the E-Commerce and New Technologies Sector via e-Learning Tools (Drigas & Kouremenos, 2005), DAVe – Gallaudet Digital

Archive Video for Education (King, 2005), or vELAP – video-based e-lectures for all participants (Kosec, Debevc, & Holzinger, 2009).

A typical user interface of the above projects shows a sign language video, without subtitles, on the left side of the window and text, figures, animations, or another video sequence in the remaining part of the window.

Consequently, we decided to use this verified and proven template to design user interfaces for the production of the e-learning course (ECDL, European Computer Driving Licence) described later in the article.

Results from other projects show that computer-based instruction is emerging as a prevalent method with regard to improving reading/writing skills through training and development of vocabulary for people with disabilities (Druin & Hendler, 2000; Hanson, 2007; Wood, 2000). Also Dubois and Vial (2000) found an increase in vocabulary learned when the training consisted of the combined presentation of spoken words, images, written words, and text in comparison to using only a subset of these methods. Debevc and Peljhan (2004) also concluded that the deaf participants who used web-based video on demand were at least as successful as the participants who used a traditional lecture method (reflected in an increase of 28% in the testing of pedagogical effectiveness), regardless of whether they were adults or children.

Outline of the study: ensuring good usability and pedagogical effectiveness

In this study, two different evaluations of the accessibility of the ECDL course material are used. The ECDL and the International Computer Driving License (ICDL) are both global standards concerning user computer skills. They offer candidates an internationally recognized certificate that is globally supported by governments, computer societies, international organizations, and commercial corporations.

How should e-learning materials be designed in order to support deaf and hard of hearing people from the viewpoint of usability? In order to clarify this, the article will focus on the following crucial issues:

- Design guidelines of e-learning material and working principles of the system. To complete ECDL courses, a short description of an e-learning course is presented.
- Descriptions of results from two evaluation tests:

  (1) Usability evaluation with Software Usability Measurement Inventory (SUMI) evaluation (Kirakowski & Corbett, 1993) with 10 deaf and hard of hearing participants.
  (2) A course pedagogical effectiveness test with the help of an adapted and extended pedagogical effectiveness index test developed in the course of this study – Adapted Pedagogical Index – AdaPI (with 116 participants, 22 of whom were deaf and hard of hearing).

The whole project is quite comprehensive and has lasted for three years (Figure 1). In the initial phase, end users' needs and demands were analyzed. E-learning materials for the deaf and hard of hearing were defined on the basis of the analysis of demands and literature guidelines. Afterwards, the ECDL e-learning

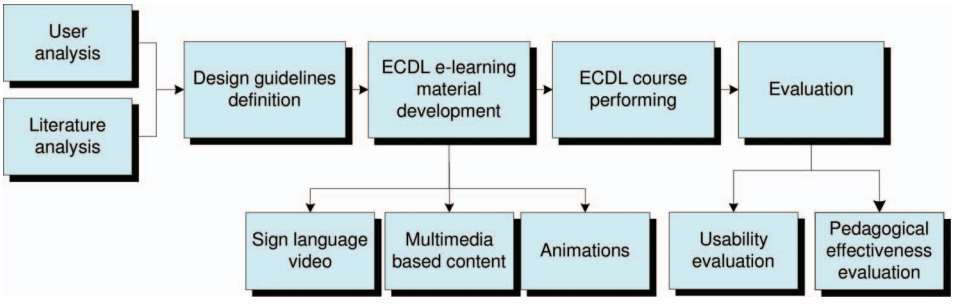

Figure 1. Diagram of the project lifecycle.

material was developed and prepared. It contains sign language video, content with animations and self-answered questions designed for both beginners and advanced users. Then the ECDL course was held for 116 participants using both e-learning materials and tutors. After the course, these 116 people, 22 of whom were deaf and hard of hearing, took the pedagogical effectiveness test. At the end, the SUMI evaluation was performed with 10 of the 22 deaf and hard of hearing participants.

Design guidelines for e-learning material for deaf and hard of hearing users

Basic design guidelines

The applied methodology has been adopted by the European Union for analysis (Smith & Mayes, 1996). It includes personal interviews with users, questionnaires, and *discussion panels* using brainstorming and personal feedback.

From past studies on such topics as hypertext information retrieval (Fajardo, Cañas, Salmeron, & Abascal, 2006), and on the basis of our own analysis, we are able to show that the accessibility of e-learning materials for the specific target group is increased when the following guidelines are taken into consideration:

(1) provide all audio information visually,
(2) assure the availability of translations of spoken and written text into sign language using quality video,
(3) provide subtitles,
(4) offer at least two difficulty levels of textual and graphical presentation,
(5) offer a dictionary and glossary of terms,
(6) include additional hyperlinks to gather detailed information,
(7) ensure quick and easily understandable navigation within the learning material,
(8) structure web-based e-learning material in an understandable and logical way,
(9) employ a simple and surveyable user interface for the learning management system (LMS) and offer tools for user interface personification,
(10) ensure that text is easily readable, paying particular attention to instructions.

Video and subtitles are of great importance in the guidelines above. Specifically, the sign language video translating the spoken text into sign language must be of

high quality, without any additional information, and be continuously present on the screen.

When developing sign language video material, the main criteria for improving the quality of video pictures as defined by Hellström (1997) are taken into consideration.

The CIF format (355×288) is the video resolution that has been used in the study. The video has been encoded for speeds above 300 kbps. This video quality has enabled the capture of all details related to the movement of hands, eyes, and mouth clearly enough to be recognized.

There are also important guidelines for subtitles. It is not possible for the deaf and hard of hearing to hear different sounds in the video, such as music, sound effects, or quickly spoken words. Even those well versed in lip-reading have problems understanding speech, since the speakers frequently turn away from the camera and, therefore, from the viewers (Hanson, 2007). Spoken text, as well as other sound information (for example, signals of the operation system, phone ringing, etc.), must be presented in the subtitles. Therefore, the subtitles are included at the bottom of the video. In the project BITEMA, research done by Debevc et al. (2003) proved that subtitles included in the sign language video are of crucial importance for the deaf and hard of hearing. Additionally, Hanson (2007) notes that it is important for the users to use verbatim subtitling as this can potentially improve reading skills.

The power of the World Wide Web (WWW) lies in its omnipresence, universality, and in the richness of multimedia. Hanson (2007) mentions that multimedia on the WWW is inherently sensory, and therefore web designers have an obligation to provide at least subtitling of audio and video materials for deaf and hard of hearing people. Also, when designing e-learning applications, standards for the development of accessible web systems, such as ISO 16071 guidelines (Guidance for Software Accessibility), ISO 9241-14 (Ergonomic requirements) (Gulliksen, Harker, & Vanderheiden, 2004) and Web Content Accessibility Guidelines (WCAG) from Web Accessibility Initiative (Duchateau, Boulay, & Burger, 2010) all need to be taken into consideration.

Recognition and identification of lip-reading, sign language, and different reading/writing skills are very diverse skills. Therefore, there is a strong need for basic guidelines that lead to system adaptation and appropriate evaluation methods in future e-learning applications.

Design guidelines for adaptive e-learning materials

Adaptive e-learning materials are defined as online learning systems. They automatically adapt to trainees or other users. The techniques mostly originate from artificial intelligence theory and are used for the needs of learning systems. According to this, adaptive systems can be split into different categories, depending on who gives the initiative, proposal, decision, and execution of activities for the change (Schneider-Hufschmidt, Kühme, & Malinowski, 1993). Analysis of users' requests has shown that full adaptation (initiative, proposal, decision, and execution done by system) is not a suitable way to change the contents of the e-learning material, since a connection loss between the user and the content and structure may result if the content is changed automatically without the user's consent.

Adaptive web-based educational systems usually include expert modules, trainee modules, tutoring modules, and user interface modules. They are all designed and

based on different criteria, such as pre-knowledge, learning curve, history of activities with e-learning materials, and item response theory (Chen, Lee, & Chen, 2005).

An e-learning application becomes adaptive through the possibility of connecting a specific trainee to the module relevant to their level of training. A question remains: what can be changed significantly in the e-learning application? According to Brusilovsky (2001, 2004), adaptive presentation and adaptive navigation in hypermedia-supported learning materials can be accomplished in the following ways:

- Adaptive presentation allows the content of web pages to adapt to the user's goals, knowledge, and other information that is stored about the user (trainee model). Generally, less experienced users are offered basic content, while advanced users are introduced to more detailed information.
- Adaptive navigation supports the trainee in orientation and navigation using visual hyperlinks. The adaptive learning system sorts, emphasizes, or partially hides links to the web page so that the user can access it more easily. This approach can be implemented in a very effective and natural way.

EDCL courses and e-learning platform

The ECDL Foundation defines the content of e-learning material designed for our study (Carpenter et al., 2000). The educational process is structured around courses that follow the method of blended learning, which can be considered a psycho-pedagogical instructional model. It defines a blended approach to the learning process (Alonso, Lopez, Manrique, & Vines, 2005; Delialioglu & Yildirim, 2007).

E-learning is provided with the help of a suitably adapted open-source LMS system: Moodle (Chavan & Pavri, 2004; Iowa State University [ISU], 2010), which is used by many educational institutions. It also offers a variety of user interface languages for an international community of training participants. Moreover, Moodle has been chosen as a platform due to its flexible and extendable characteristics. Moodle is developed on the popular Linux, Apache, MySQL, and PHP platform (LAMP).

Additionally, PostgreSQL can be used instead of MySQL. The flexible technical requirements make it possible to install and evaluate Moodle on almost any computer including those on shared web servers. It is also usable for both mixed and augmented reality applications (Christian, Krieger, Holzinger, & Behringer, 2007) as well as for X-Media approaches (Holzinger, Nischelwitzer, & Kickmeier-Rust, 2006). The GPL, well-documented PHP code, an active developer community, and a modular design make it possible to customize Moodle and integrate it with other open-source software. For the users, Moodle requires a web browser and an Internet connection (Dougiamas & Taylor, 2003).

Moodle has been used for the management of e-content and to supervise the activities and progress of the participants. Moodle contains tools and functions that are required as basic support for e-learning, such as multimedia support, forums, questionnaires, questioning, chat, e-mail, and news. In the presented study, almost all of the offered tools and functions are used.

Description of the developed system

The e-learning content in Moodle is offered in the form of short web pages. The design is deliberately kept compact. Complex graphic elements are avoided in

order to reduce the influence of disturbing factors that could distract from the content.

Navigation and structure of the e-learning course

Moodle enables intuitive navigation between individual system levels and activities. Navigation within the e-learning material is enabled by hyperlinks in the form of:

- course lists;
- chapter lists;
- lists of tools inside each course;
- path/locator, which changes dynamically according to the chosen link in the hierarchy.

Because navigation through the e-learning materials is easy and intuitive, the navigation elements are not translated into sign language.

The whole course is composed of sections, each containing short chapters with a maximum of two pages to be processed in the current week. Within a chapter, the user can navigate between pages using the buttons on the right side of the window.

All material for the deaf and hard of hearing is exactly the same as that for their hearing colleagues, with the addition of an interpreter. The available space for content presentation is limited by the size of the screen and the resolution of the computer monitor. Since the deaf and hard of hearing will have an additional video player window open, the list of all sub-chapters which is present for other users must be removed.

Therefore, the materials have been designed so that a particular web page (sub-chapter) involves at most two screens (Figure 2). The left-hand side contains a sign language video with subtitles and the right-hand side displays simply designed content with basic navigation buttons. There are three such buttons: previous topic, list of contents, and next topic. The user can consecutively browse the topics forwards and backwards. Also, there is an active button for the table of contents, which returns the user to the first page of a certain chapter with a list of all sub-chapters or topics.

Sign language video

Another advantage is the loading speed of web pages. Deaf and hard of hearing people can quickly become impatient and therefore the sign language video should load quickly. To make this possible, the sign language video is encoded as a streaming media and put on the assigned quality server with a high-speed broadband connection. However, the same video could be put on a CD-ROM or DVD-ROM.

Marker tags are inserted into the sign language video in order to ensure quick and smooth transitions between the web pages with sign language videos. Consequently, the video is segmented into smaller sections that correspond to the divided units. Markers enable even faster loading of the sign language video in MS Internet Explorer.

Figure 2 shows a sign language video on the left part of the window. In this example, the signer is giving a direct translation of the text positioned on the right

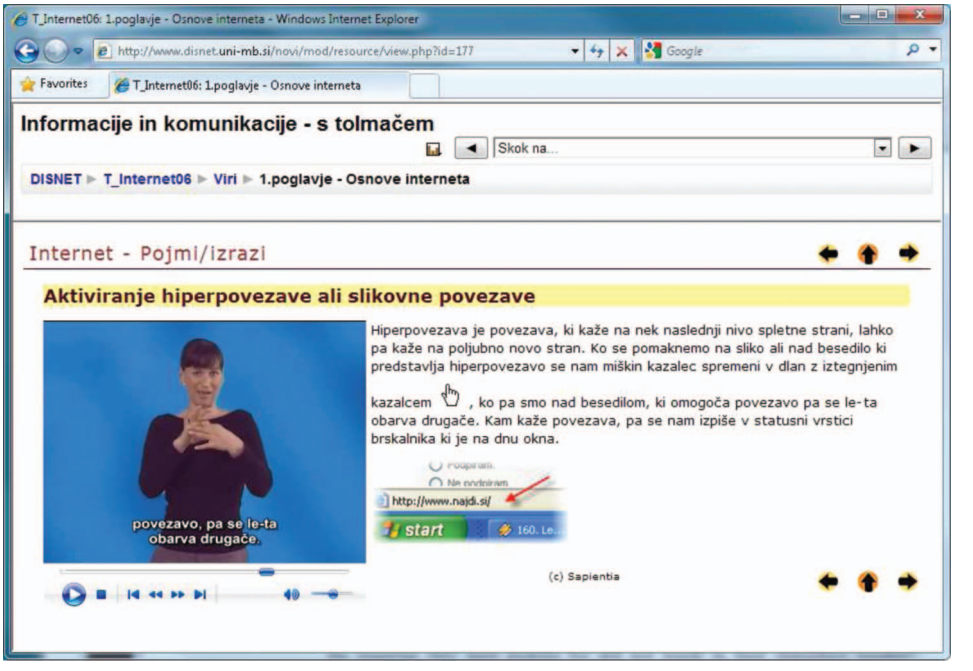

Figure 2. ECDL for deaf and hard of hearing people – view of material with sign language video and subtitles (in Slovene language).

side of the screen. Subtitles are positioned at the bottom. Generally, the text in the e-learning course is presented as plain language, without foreign words or terms that are difficult to understand. This ensures that all users are able to understand both the wording and the material.

Adaptation process of the e-learning course

General adaptation is provided as defined by Schneider-Hufschmidt, Kühme, and Malinowski (1993). In the cited work, the authors deal with the area of intelligent and adaptive user interfaces, which is still of interest to the research community. Their studies resulted in the creation of guidelines which are still accurate. This is because they presented a stable theoretical base for adaptivity in human–computer interaction and for building prototypes that show features of adaptivity in ''real-life'' interfaces. Therefore, the proposed system offers both initiative and proposals. The other two activities (decision and execution) are carried out by the user. The system offers the content within individual topics, which are separated into two distinct levels: basic and advanced. The basic level is designed for beginners. The advanced level is designated for users with basic computer skills, and aims at expanding their basic knowledge. In order to avoid the discrimination of different kinds of users, both basic and advanced levels are offered.

Revision of the acquired knowledge can be stated as a key factor for successful and effective learning. Therefore, short questions are posed at the end of each lesson. The answers are not registered and the user can answer the questions several times.

Evaluation of the e-learning material

Methods and materials

The choice of an appropriate methodology for evaluation greatly affects the successful usage of any educational system. However, not many methods are available which are useful and useable for the proper evaluation of e-learning courses (Zaharias, 2006).

We have selected a variety of methods from many experts for review (Achtemeier, Morris, & Finnegan, 2003; Costabile, Roselli, Lanzilotti, Ardito, & Rossano, 2007; Holzinger, 2002; Lanzilotti, Ardito, Costabile, & De Angeli, 2006; Sonwalkar, 2002; Squires & Preece, 1999).

Different views of the project were evaluated and methods were adapted for the individual aspect of evaluation. Areas that were evaluated included the evaluation of end-user friendliness of e-materials, the estimation of the general opinion of participants about the course and its adaptation to disabled people, and the evaluation of the effectiveness of both pedagogical approach and the course as a whole.

Table 1 presents methods of evaluation (SUMI evaluation and course effectiveness) and the way they were used.

From the 116 unemployed people included in the evaluation, 14 were deaf and eight were hard of hearing. Thirteen of these participants were females and nine were males. Their computer literacy was on a beginner's level. All the participants from the target group were experienced in sign language and they were also able to perform lip-reading. All 22 deaf and hard of hearing participants used adapted ECDL e-learning materials that included sign language video as discussed above. The small number of deaf and hard of hearing participants in the project as compared with the total number of participants was due to the relatively small population of deaf and hard of hearing persons, which was estimated to be just less than the one per thousand in the school-age population and continues to decrease (Mitchell & Karchmer, 2006).

After the course, the participants completed two questionnaires: the SUMI evaluation questionnaire (Kirakowski & Corbett, 1993), and subsequently a questionnaire to acquire an Adapted Pedagogical Index (AdaPI) as defined by Šnajder, Verlič, Povalej, and Debevc (2007), which was based on Sonwalkar's (2002) Pedagogical Effectiveness Index (PEI) questionnaire.

Table 1. Evaluation methods.

	SUMI evaluation	Course effectiveness
Purpose	User testing	Test of pedagogical variables
Phase of the project	Final phase	Final phase
Object of testing	E-materials	Individual courses
Target population	Users	Users
Number of deaf users	10	14
Number of hard of hearing users	0	8
Number of users without disabilities	65	94
Number of evaluators	2	3

SUMI evaluation

The usability of the system was tested by 10 of 22 deaf participants. According to the guidelines for SUMI evaluation, a sample of eight end users is sufficient to obtain reliable statistical results. All deaf participants had no basic computer literacy or web browser experience before joining this e-learning course.

SUMI evaluation includes a questionnaire described by Kirakowski and Corbett (1993). It consists of 50 items for which the user selects one of three responses (“agree,” “don’t know,” “disagree”).

The questionnaire results are separated into the following five usability subscales: *efficiency, affect, helpfulness, control*, and *learnability*.

Once the questionnaires were completed, the web software program that comes with the SUMI package scores them and compares the results to the standardization database. A system that achieves a score in the 40–60 range is comparable in usability to most successful commercial products (the standardization database does include scores below and above that range).

The results shown in Figure 3 are presented in terms of the mean and the 95% upper and lower confidence levels (UCL and LCL). These descriptive statistics are given for the global usability scale and each of five usability sub-scales.

In terms of usability, sub-scales show that results are generally consistent, and nearly all fall within the desired range. The exception is the learnability sub-scale (learnability item in Figure 3), which falls below the desired range.

Deaf and hard of hearing participants had differing opinions about the application’s efficiency and several problems with the control of the application, which can be seen as control item in Figure 3.

This might be explained by the fact that there was a difference between user groups regarding computer literacy. The lower efficiency level shows that users may not always know what to do next or the software may sometimes work inconsistently. A high helpfulness level, on the other hand, shows that this application communicates clearly with the users. An overall outcome of the SUMI evaluation questionnaire (global item in Figure 3) confirms that the system was usable and suitable for the next evaluation, pedagogical effectiveness evaluation.

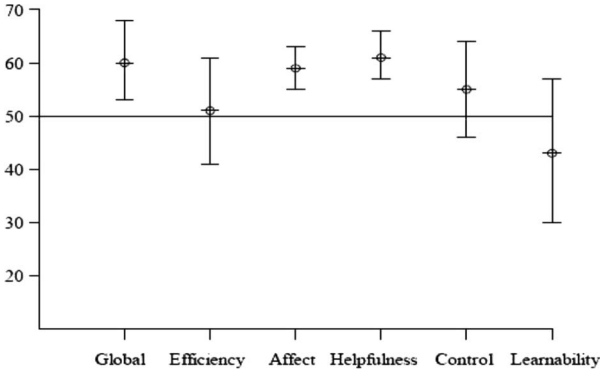

Figure 3. Comparison of global and subscale usability scores (SUMI evaluation).

Course effectiveness – Pedagogical Effectiveness Index

The basic pedagogical process is often idealistically defined as a systematic transfer of knowledge or skills from a tutor to a learner. However, this process is much more complicated, and it encompasses a variety of different factors, such as motivation, the individual's needs, learning materials, the learner's learning style, and the instructor's teaching style (Hu, Hui, Clark, & Tam, 2007; Ratcliffe, Thomas, Ellis, & Thomasson, 2003).

For simple evaluation, it would be sufficient to analyze pre-knowledge and post-knowledge exams and to determine its effectiveness (Valenti, Panti, & Leo, 2003). However, this simple method would say very little about all the other factors that are included in the pedagogical process and that is why there is a need for a more thorough measurement of pedagogical effectiveness. Our proposed method aims for the holistic analysis of the pedagogical effectiveness of the courses. In order to conduct our evaluation, an AdaPI was developed.

Adapted Pedagogical Index

Pedagogical effectiveness of the adapted ECDL e-learning materials is evaluated on the basis of the PEI proposed by Sonwalkar (2002). This method has been adapted to the disability of the deaf and hard of hearing participants, and named: AdaPI (Šnajder et al., 2007).

While the AdaPI is similar to the PEI in that both consist of three dimensions, there is a difference in the components that compose each of these dimensions. Table 2 shows the structure and comparison of both the original PEI and the newly developed AdaPI.

Both indexes, the PEI and AdaPI, are composed of three dimensions – *learning styles, media, and interaction*.

The first dimension, *learning styles* in the PEI, is built from five components. However, in the AdaPI, instead of the inductive and deductive components, the VAK (visual, auditory and kinesthetic) learning style (Burton, 2007) is introduced. The reasons for switching the two are due to disabilities common to participants in the study. People with disabilities that deprive them of the use of one or more senses tend to increase the use of their remaining senses. For instance, if someone has hearing difficulties, they will strengthen their ability to see (Hanson, 2007).

Table 2. Comparison of the structure of the original Pedagogy Effectiveness Index (PEI) with the Adapted Pedagogical Index (AdaPI).

Sonwalker PEI			AdaPI		
Learning styles	Media	Interaction	Learning styles	Media	Interaction
Apprenticeship	Text	Feedback	Apprenticeship	Text	Feedback
Incidental learning	Graphics	Revision	Incidental learning	Graphics	Revision
Discovery	Audio	E-mail	Discovery	Audio	E-mail
Inductive	Animation	Discussion	VAK styles	Animation	Discussion
Deductive	Simulation	Bulletin		Material arrangement	Tutor's role

The second dimension media in the AdaPI is built of five components – *text, graphics, audio, animation*, and *material arrangement*. In comparison to the PEI, the difference is that *video* and *simulation* components are now joined with *animation*. The component *material arrangement* is added, which represents an important factor for easing the studying process for deaf and hard of hearing.

The third dimension is *interaction*. In the AdaPI, it emphasizes the significance of interaction between tutor, participant, and material. The dimension retains four components that are proposed by Sonwalkar (2002) and replaces the last one (Bulletin) with *Tutor's role* (Salmon, 2004).

Research instrument, calculating the AdaPI, and results

In the research conducted by Šnajder et al. (2007), all 116 unemployed participants were involved in testing the effectiveness of the whole course, as well as the suitability of the adapted questionnaire, regardless of the disability level of the participants. Out of all participants, 22 people were deaf or hard of hearing. Participants' opinions were gathered by filling in the questionnaires. After gathering and processing data, the AdaPI was calculated with the following formula:

$$\text{AdaPI} = \sum_1^n v_i \tag{1}$$

where all values of dimensions (v_i) are averaged.

The value of the AdaPI can range from 0 to 1. Calculated AdaPI of the courses presented within this study is 0.68. Since the value of the AdaPI exceeds the value 0.5, it can be concluded that the project is successful from the pedagogical point of view.

Course satisfaction is an important psychological aspect of every learning process. If the participants are satisfied with the pedagogical process, it is more likely that they will use the knowledge gained more effectively in real life. Therefore, both knowledge gained and participants' satisfaction with the course influence the final pedagogical effectiveness of all courses and therefore the whole project.

Conclusions

In the course of this research, an adapted e-learning environment for people with disabilities, especially for deaf and hard of hearing people, is presented. The e-learning materials presented take into consideration the requirements and needs of deaf and hard of hearing people. At the same time, an improved approach for sign language video retrieval is introduced. The most important features include speeding up the loading of sign language video with subtitles, quickly switching to the next page of the e-learning content, and utilizing shorter and more understandable e-learning text. To enable these features, sign language video is encoded as a streaming media together with marker tags.

It has been demonstrated that it is useful to apply more than one evaluation method. The first method is usability testing with the use of the SUMI evaluation method. After the usability testing is confirmed, the pedagogical effectiveness evaluation can be performed. Pedagogical effectiveness evaluation is based on the developed AdaPI method. The advanced AdaPI method includes more questions

than the original PEI method, and thereby covers the requirements and needs of people with disabilities.

According to the results of the AdaPI questionnaire, it can be concluded that the research is successful from a pedagogical point of view as well, since the AdaPI value of 0.68 exceeds the minimum required value 0.5. It is evident from the results that tutors play a crucial role in the learning process and that people with disabilities need additional help and advice in familiarizing themselves with all the available technologies.

Our system is currently only available in Slovene, and there is still some work that needs to be done in the future. There is still the challenge of designing web pages with transparent sign language video. This would contribute toward keeping the usual structure and design of the web page. The next challenge is to develop fully adaptive e-learning materials that would guide people with disabilities and suggest the most appropriate and accessible way to go through the materials. Additionally, the system can be easily re-designed for English and other languages.

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References

Achtemeier, S.D., Morris, L.V., & Finnegan, C.L. (2003). Considerations for developing evaluations of online courses. *Journal of Asynchronous Learning Networks*, *7*(1), 1–13.

Alonso, F., Lopez, G., Manrique, D., & Vines, J.M. (2005). An instructional model for web-based e-learning education with a blended learning process approach. *British Journal of Educational Technology*, *36*, 217–235.

Begoray, J.A. (1990). An introduction to hypermedia issues, systems and application areas. *International Journal of Man-Machine Studies*, *33*, 121–147.

Brown, D.J., Powell, H.M., Battersby, S., Lewis, J., Shopland, N., & Yazdanparast, M. (2002). Design guidelines for interactive multimedia learning environments to promote social inclusion. *Disability and Rehabilitation*, *24*, 587–597.

Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction*, *11*, 87–110.

Brusilovsky, P. (2004). KnowledgeTree: A distributed architecture for adaptive e-learning. In *Proceedings of the international conference ACM WWW* (pp. 104–113). New York: Association for Computing Machinery.

Burton, D. (2007). Psycho-pedagogy and personalised learning. *Journal of Education for Teaching: International Research and Pedagogy*, *33*(1), 5–17.

Carpenter, D., Dolan, D., Leahy, D., & Sherwood-Smith, M. (2000). ECDL/ICDL: A global computer literacy initiative. In *Proceedings of the conference on educational uses of information and communication technologies (ICEUT)*. Beijing: Publishing House of Electronics Industry (PHEI).

Carr, S. (2000, February 11). As distance education comes of age, the challenge is keeping the students. *The Chronicle of Higher Education*. Retrieved from http://chronicle.com/article/As-Distance-Education-Comes-of/14334

Chavan, A. & Pavri, S. (2004, December 1). Open-source learning management with Moodle. *Linux Journal*. Retrieved from http://www.linuxjournal.com/article/7478

Chen, C.M., Lee, H.M., & Chen, Y.H. (2005). Personalized e-learning system using item response theory. *Computers & Education*, *44*, 237–255.

Christian, J., Krieger, H., Holzinger, A., & Behringer, R. (2007). Virtual and mixed reality interface for e-training: Examples of applications in ultralight/light sport aircraft maintenance. In C. Stephanidis (Ed.), *Lecture notes in computer science (LNCS 4556)* (pp. 520–529). Berlin, Heidelberg: Springer. doi:10.1007/978-3-540-73283-9_58.

Clark, R.E. (1994). Media will never influence learning. *Educational Technology Research and Development*, *42*, 21–29.

Costabile, M.F., Roselli, T., Lanzilotti, R., Ardito, C., & Rossano, V. (2007). A holistic approach to the evaluation of e-learning systems. In C. Stephanidis (Ed.), *Lecture notes in computer science (LNCS 4556)* (pp. 520–529). Berlin, Heidelberg: Springer. doi:10.1007/978-3-540-73283–9_59.

Debevc, M. & Peljhan, Z. (2004). The role of video technology in on-line lectures for the deaf. *Disability and Rehabilitation*, *26*, 1048–1059.

Debevc, M., Zorič-Venuti, M., & Peljhan, Ž. (2003). *E-learning material planning and preparation* (Report of the European project BITEMA – Bilingual Teaching Material For The Deaf by Means of ICT). Maribor, Slovenia: University of Maribor. Retrieved from http://www.bitema.uni-mb.si/Documents/PDF/E_learning_material_writing.pdf

Delialioglu, O. & Yildirim, Z. (2007). Students' perceptions on effective dimensions of interactive learning in a blended learning environment. *Educational Technology & Society*, *10*, 133–146.

Dougiamas, M. & Taylor, P. (2003). Moodle: Using learning communities to create an open source course management system. In *Proceedings of the world conference on educational multimedia, hypermedia and telecommunications* (pp. 171–178). Chesapeake, VA: Association for the Advancement of Computing in Education.

Drigas, A.S. & Kouremenos, D. (2005). An e-learning management system for the deaf people. *WSEAS Transaction on Advances in Engineering Education*, *2*, 20–24.

Druin, A. & Hendler, J. (2000). *Robots for kids: Exploring new technologies for learning*. San Francisco: Morgan Kaufmann.

Dubois, M. & Vial, I. (2000). Multimedia design: The effects of relating multimodal information. *Journal of Assisted Computer Learning*, *16*, 157–165.

Duchateau, S., Boulay, D., & Burger, D. (2010). Assessing WCAG 2.0 conformance in practice. In K. Miesenberger, J. Klaus, W. Zagler, & A. Karshmer (Eds.), *Lecture notes in computer science (LNCS 6179)* (pp. 408–412). Berlin, Heidelberg: Springer. doi:10.1007/978–3–642–14097–6_65.

Fajardo, I., Cañas, J.J., Salmeron, L., & Abascal, J. (2006). Improving deaf users' accessibility in hypertext information retrieval: Are graphical interfaces useful for them? *Behaviour & Information Technology*, *25*, 455–467.

Gulliksen, J., Harker, S., & Vanderheiden, G. (2004). Guidelines, standards, methods and processes for software accessibility. *International Journal on Universal Access in the Information Society*, *3*(1), 1–5.

Hanson, V. (2007). Computing technologies for deaf and hard of hearing users. In A.J. Sears & A. Julie (Eds.), *Human–computer interaction handbook: Fundamentals, evolving technologies, and emerging applications, human factors and ergonomics* (pp. 886–893). New York: CRC Press.

Hellström, G. (1997). Quality measurement on video communication for sign language. In *Proceedings of the 16th international symposium on human factors in telecommunications* (pp. 217–224). Oslo, Norway.

Hilzensauer, M. (2006). Information technology for deaf people. In N. Ichalkaranje, A. Ichalkaranje, & L.C. Jain (Eds.), *Intelligent paradigms for assistive and preventive healthcare* (pp. 183–206). Berlin, Heidelberg: Springer.

Holzinger, A. (2000). *Basiswissen Multimedia Band 2: Lernen*. Würzburg: Vogel Buchverlag.

Holzinger, A. (2002). *Multimedia basics – Design* (Vol. III). New Delhi: Laxmi Publications.

Holzinger, A., Kickmeier-Rust, M., Wassertheurer, S., & Hessinger, M. (2009). Learning performance with interactive simulations in medical education: Lessons learned from results of learning complex physiological models with the HAEMOdynamics SIMulator. *Computers & Education*, *52*(1), 292–301.

Holzinger, A., Nischelwitzer, A.K., & Kickmeier-Rust, M.D. (2006). *Pervasive e-education supports life long learning: Some examples of X-media learning objects*. In M. Jones, A. Krieger, F. Reichl, & A. Steiner (Eds.), *Proceedings of the 10th IACEE world conference on continuing engineering education* (pp. 20–26). Vienna, Austria: Vienna University of Technology.

Hu, P.J.H., Hui, W., Clark, T.H.K., & Tam, K.Y. (2007). Technology-assisted learning and learning style: A longitudinal field experiment. *IEEE Transactions on Systems Man and Cybernetics Part A – Systems and Humans*, *37*, 1099–1112.

Iowa State University. (2010). *ISUComm Moodle Tutorials*. Retrieved from http://courses.isucomm.iastate.edu/course/view.php?id=698

King, C. (2005). Gallaudet digital archive video for education (DAVe). In *International symposium instructional technology and education of the deaf*. Rochester, NY: National Technical Institute for the Deaf, Rochester Institute of Technology.

Kirakowski, J., & Corbett, M. (1993). SUMI: The software usability measurement inventory. *British Journal of Educational Technology*, *24*, 210–212.

Kosec, P., Debevc, M., & Holzinger, A. (2009). Towards equal opportunities in computer engineering education: Design, development and evaluation of video-based e-lectures. *International Journal of Engineering Education*, *25*, 763–771.

Kozma, R.B. (1993). Will media influence learning: Reframing the debate. *Educational Technology Research and Development, 42*, 7–19.

Kronreif, G., Dotter, F., Bergmeister, E., Krammer, K., Hilzensauer, M., Okorn, I., … Barreto, B. (2000). SMILE: Demonstration of a cognitively oriented solution to the improvement of written language competence of deaf people. In *Proceedings of the 7th international conference on computers helping people with special needs – ICCHP 2000*. Karlsruhe, Germany: Österreichische Computer Gesellschaft.

Lanzilotti, R., Ardito, C., Costabile, M.F., & De Angeli, A. (2006). eLSE methodology: A systematic approach to the e-learning systems evaluation. *Educational Technology & Society*, *9*, 42–53.

Mitchell, R.E. & Karchmer, M.A. (2006). Demographics of deaf education: More students in more places. *American Annals of the Deaf*, *151*, 95–104.

Mungania, P. (2003). *The seven e-learning barriers facing employees (Final Report)*. Louisville, KY: University of Louisville. Retrieved from http://www.websm.org/uploadi/editor/1140716015Mungania_Final_Report.pdf

Ratcliffe, M., Thomas, L., Ellis, W., & Thomasson, B. (2003). Capturing collaborative designs to assist the pedagogical process. *SIGCSE Bulletin*, *35*, 79–83.

Rogers, P.L. (2002). *Designing instruction for technology-enhanced learning*. Hershey, PA: Idea Group Publishing.

Salmon, G. (2004). *E-moderating: The key to teaching & learning online*. London: Routledge Falmer.

Sandars, J. & Morrison, C. (2007). What is the net generation? The challenge for future medical education. *Medical Teacher*, *29*, 85–88.

Schneider-Hufschmidt, M., Kühme, T., & Malinowski, U. (Eds.). (1993). *Adaptive user interfaces: Principles and practise*. Amsterdam: North Holland Elsevier.

Smith, C. & Mayes, T. (1996). *Telematics applications for education and training: Usability guide. DGXIII Project ICBL*. Brussels: Commission of the European Communities.

Šnajder, M., Verlič, M., Povalej, P., & Debevc, M. (2007). Pedagogical evaluation of e-learning courses – Adapted Pedagogical Index. In *Proceedings of the international conference on interactive computer aided learning*. Villach, Austria. Retrieved from http://halshs.archives-ouvertes.fr/docs/00/19/72/26/PDF/42_Final_Paper.pdf

Sonwalkar, N. (2002). A new methodology for evaluation: The pedagogical rating of online courses. *Syllabus*, *15*, 18–21.

Squires, D. & Preece, J. (1999). Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, *11*, 467–483.

Straetz, K., Kaibel, A., Raithel, V., Specht, M., Grote, K., & Kramer, F. (2004). An e-learning environment for deaf adults. In *Conference proceedings 8th ERCIM workshop "user interfaces for all"*. Vienna, Austria: Springer.

Theofanos, M.F. & Redish, J. (2005). Helping low-vision and other users with Web sites that meet their needs: Is one site for all feasible? *Technical Communication*, *52*(1), 9–20.

Tyler-Smith, K. (2006). Early attrition among first time eLearners: A review of factors that contribute to drop-out, withdrawal and non-completion rates of adult learners undertaking eLearning programmes. *Journal of Online Learning and Teaching*, *2*, 73–85. Retrieved from http://jolt.merlot.org/documents/Vol2_No2_TylerSmith_000.pdf

Valenti, S., Panti, M., & Leo, T. (2003). Relevant issues for the design of a successful web-based instructional system: Modaspectra. In A.K. Aggarwal (Ed.), *Web-based education: Learning from experience* (pp. 371–397). Hershey, PA: IGI Publishing.

Williams, P., Jamali, H.R., & Nicholas, D. (2006). Using information and communication technology with special educational needs students. *Aslib Proceedings: New Information Perspectives*, *57*, 539–553.

Wood, J. (2000). Can software support children's vocabulary development? *Language Learning & Technology*, *5*, 166–201.

Yang, H.J., Lay, Y.L., Liou, Y.C., Tsao, W.Y., & Lin, C.K. (2007). Development and evaluation of computer-aided music-learning system for the hearing impaired. *Journal of Computer Assisted Learning*, *23*, 466–476.

Zaharias, P. (2006). A usability evaluation method for e-learning: Focus on motivation to learn. In *Conference on human factors in computing systems* (pp. 1571–1576). Montreal, Quebec, Canada: Association for Computing Machinery.