Accessible and Adaptive e-Learning Materials: Considerations for Design and Development

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Abstract. The aspect of accessibility and adaptivity is important for future of e-Learning applications. Creating e-Learning applications for everybody, including people with special needs, remains the question. The problem with development of e-Learning applications for everybody is that learner ability and weaknesses are usually neglected as important factors while developing applications. Most of nowadays applications offer lots of unclear information, unsuitable contents and non-adapted mechanisms. This paper suggests basic guidelines for successful design and structuring accessible and adaptive e-Learning applications that consider the requests and needs of people with special needs. It provides an example of design and realization of e-Learning application for receiving ECDL certificate, which includes easy adaptivity and basic accessibility factors. Experimental results of usability testing and pedagogical effectiveness have shown that material, designed following these guidelines, is appropriate and that there must be extra attention paid to learnability factor in the future.

Keywords: e-Learning, accessibility, adaptive user interfaces, usability, evaluation, people with special needs.

1 Introduction

With the development of computers and related technologies, information and computing technology (ICT) has broadened its aspects to the educational area. ICT offers support to students while learning, acquiring knowledge and communicating on several levels. To the teachers, ICT offers support in providing necessary material for distance learning, for informing students, communicating with them and evaluating their results.

Researches have shown that learning with ICT is easier and more effective, especially if ICT is used in the educational process. The researches by Parlangeli et al. [1], Kulik [2] and Bosco [3], who compared traditional learning methods with learning by multimedia systems, showed higher effectiveness of learning, if ICT was used as learning framework. Kulik in his research has shown that students spent 70% less time for learning in some cases then by using classical learning methods. This has proven to be valid especially for material, which included animations and video presentations. Chou and Lou [4] and Schulz et al. [5] have also shown in their

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research, that distance learning using web-based virtual learning environment is effective and useful.

Due to this effectiveness of education using ICT, the question arises whether nowadays e-Learning applications are suitable and successful also for education of all the people, including people with special needs. In other words, how should be the outlook and usability of e-Learning applications in the future, in order to be usable for all the people? The problem in development e-Learning applications is the variety of disturbances and impediments, which people with special needs are having, requesting more or less adapted execution of breeding and education with additional help, which can be either technical or of inter-personal nature [6].

In order to control the impact of e-Learning applications onto success of education, we have used modified (adapted) Course Management Systems (CMS) Moodle for European Computer Driving License (ECDL) of e-materials [7] for qualifying poeple with special needs. We have used additional functionality, which shows characteristics of e-Learning applications in the future. This paper presents following items, which are result of experiences and research during this project:

- Basic guidelines for designing and structuring accessible and adaptive e-Learning applications according to the analysis of needs and requirements of the users.
- Possibilities for developing advanced adaptive e-Learning materials, taking into account different adaptivity criteria
- Explanation of the chosen design of e-materials and working principles of the system. The course entitled “Basic Concepts of Information Technologies” as a part of the European Computer Driving License (ECDL) will be presented as an illustrative example.
- Presentation of evaluation methods focused on the object of evaluation, such as: evaluation of usability of e-materials and evaluation of the pedagogical efficiency.

2 Related Works and Project Related e-Learning Framework

The basics of problem solution for improving educational level of people with special needs using e-Learning applications can be found in other projects, like SMILE [8], ShowVideo [9] and Barrierefrei [10]. The results of other research have already shown that computer aided learning for hearing disabled people is effective enough as additional method for training and development of speech capabilities [11]. Following this, e-Learning applications could be additional help while learning when repeating and refreshing, what has been learnt, at home. This makes the student capable to learn and capture information from study material in verbal and multimedia form, which is the closest to him.

However, all projects so far have focused on a certain group of people with special needs and limited functionality. The results of SMILE project can be, for example, used only as a dictionary for hearing impaired people. The Barrierefrei project is the only one, which tries to equally offer material to different people with special needs. The project is suitable for seeing impaired people, but it does not have sign language video included to be suitable also for hearing disabled people.

This has led us to use curriculum that had been defined by the ECDL Foundation as development and testing basis for e-Learning materials in our project. ECDL/ICDL are the global standards for end-user computer skills, offering candidates an internationally recognized certificate that is globally supported by governments, computer societies, international organizations and commercial corporations.

Education process took place in the form of courses, following the method of blended learning [12]. In the year 2006, in total 20.000 unemployed people in Slovenia were educated for computer literacy within the frame of PHARE 2003 Programme; out of that 300 people in our project– 60 of them were people with special needs.

3 Basic Guidelines for Designing and Structuring Future Accessible and Adaptive Learning Management System

For the analysis of needs and requirements of people and for setting the directives for development of e-Learning applications for everybody, including people with special needs we have used analysis methodology for ICT projects defined by European committee [13]. Methodology includes personal interviews with end-users, questionnaires and organization of discussion panels with brainstorming and feedback. For future user interfaces as well as for the materials, there has been general request for e-Learning applications to contain both accessibility and adaptivity, where there must be a strict distinction between these two terms.

The term "accessible e-Learning materials" is used for e-Learning material that is accessible taking into account physical, sensorial and mental capabilities of users. Furthermore, it presumes that the content is presented in a clear and simple way, as well as that simple, understandable navigation between the pages is used.

The term "adaptive e-Learning materials" means that the content of e-Learning material can be adaptively changed according to user's capabilities and activities. Here, the content could be adapted regarding the pre-knowledge, learning curve, history of activities with e-Learning materials, number of errors in questionnaires and on user profile (visual, hearing centered, age, type of disability).

The analysis had given us some basic guidelines for creating adaptive and accessible e-Learning applications.

3.1 Accessible e-Learning Materials - Basic Guidelines

The highest power of World Wide Web is its wideness and universality. Therefore is the accessibility factor one of the most important aspects. Accessibility is the area, which helps ensuring that all the users can use interactive e-content. Planning and design of accessible e-content needs to become integral part of e-content development and must follow the instructions for design, required by people with special needs.

Table 1 presents some of the most important guidelines for design of accessible e-content, which we have determined using analysis of needs and requirements of people with special needs and considering the instructions by Web Content Accessibility Guidelines (WCAG) from Web Accessibility Initiative (WAI) [14].

Table 1. Impairment and technical solutions

Impairment	Solution for e-Learning content development
Partial sight	Higher number of larger images, font scaling option, color change option, additional information for images, increased involvement of audio information. Hardware based accessibility (screen magnifiers)
Blindness	Verbal image and video descriptions, verbal subtitles, verbal navigation, audio text description, hardware based accessibility (screen readers, Braille keyboards)
Hard of hearing	Video subtitles, image and video oriented content, textual communication option
Deaf	Video subtitles, sign language video, additional glossary in sign language, easy reading content
Impaired dexterity (such as arthritis, tremor, lack of limbs)	Hardware based accessibility (keyboards, touch panels)
Impaired cognition (such as memory, concentration)	Logical and easy navigation, very easy reading content, larger number of image material

When designing e-Learning applications for people with special needs, standards for development of accessible web systems, like ISO 16071 guidelines (Guidance for Software Accessibility) and ISO 9241-14 (Ergonomic requirements) [15], need to be taken into consideration in addition to the guidelines presented in Table 1.

Next aspect of development is the trial of realization of one system for all different users. This case requires system adaptivity in future e-Learning applications.

3.2 Adaptive e-Learning Material - Basic Guidelines

Adaptive e-Learning materials in our project are defined as online learning system, which automatically adapts to students or other users in intelligent way. The techniques mostly originate from artificial intelligence theory and are used for the needs of teaching learning systems to adapt individual needs and user wishes. According to this, adaptive systems can further be split into subsections, depending on who gives initiative, proposal, decision and execution of activities for the change [16]. Analysis of users' requests have shown, that full adaptivity is not suitable for changing the contents of learning material, since it may cause losing a connection between the user and the content and structure, if the content gets automatically changed without user's consent.

Adaptive web based educational systems usually include expert modules, student modules, tutoring modules and user interface module, all designed based on different criteria, such as: pre-knowledge, learning curve, history of activities with e-Learning materials, and item response theory [17]. As result of connecting certain (students and learning) and these modules, adaptivity of e-Learning application is offered to users.

The question, what can be changed in the e-Learning application, remains. According to Brusilovsky [18], the adaptive presentation and adaptive navigation can be done in following ways in hypermedia supported learning materials:

- *Adaptive presentation* presents option for the content of hypermedia designed web page to adapt in sense of user's goals, knowledge and other information that is stored about the user (student's model). In general, it is required that less experienced users get offered more simple content, whilst advanced users get presented with additional, in depth information.
- The goal of *Adaptive navigation* is to support student in orientation and navigation using visual hyperlinks. Adaptive learning system sorts, emphasizes or partially hides links to the web page, so that the user can easier access it. This approach can be implemented in very effective and natural way.

The basic task of development of adaptive e-Learning applications is to create simple, efficient and effective learning material. However, special attention needs to be paid into creation of adaptive systems, so that the user gets offered only adaptivity of one small part of whole course management system (e.g. navigation or contents), otherwise the user may lose the clarity and navigability of learning process.

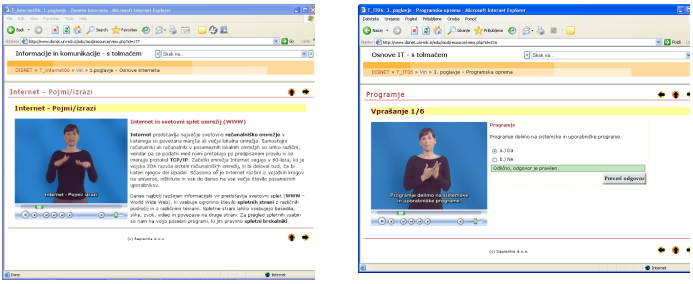
4 Accessible and Adaptive e-Learning Application - ECDL e-Learning Example

Having in mind the guidelines for designing and implementing e-Learning systems for people with special needs listed in previous section we decided to present the content in the form of web (HTML) pages inside of Moodle CMS system [19]. We intentionally kept the design simple and avoid the complex graphic elements in order to reduce the influence of disturbing factors that could distract attention from the content.

We designed basic adaptivity, in which system offers initiative and proposal; other activities (decision and execution) were carried out by the user. System therefore offers the content within individual topics, which is divided according to two defined levels: basic and advanced. The basic levels were designed for users having only basic computer skills or even complete beginners. The advanced level was designed for users, experienced in basic work with the computer with a goal to upgrade their knowledge with new information. Users who gained/repeat the knowledge foreseen for the basic level quicker could also see the chapters at the advanced level and prepare themselves for final ECDL exam.

According to accessibility guidelines, we have designed the materials in such a way that particular web page was divided into two screens (Figure 1a). Left hand side shows sign language video and the right hand side simple designed content with basic navigation buttons.

Next aspect of accessibility was implemented with the use of simple and usable navigation inside of e-Learning material. In this way, the user always knows in which module one works and which activities are being used. Important aspect at the accessibility design was the loading speed of web pages, especially video. Therefore video includes marker tags and was segmented into smaller sections that correspond



a) b)

Fig. 1. ECDL for deaf and hard of hearing people – a) classical view of material with sign language interpreter b) material with question for individual knowledge testing

to the units the material was divided into. This solution has extremely fastened video and web page loading time. Assessment of the knowledge can be stated as a key factor for successful and effective learning. Therefore, at the end of each lesson we include short questions (Figure 1b). The answers were not registered and the user could answer the questions several times. After answering, the system responded whether the answer was correct or not. If reasonable, there was also a short explanation in case of an incorrect answer.

5 Pedagogical and Usability Testing - Results

The decision of suitable evaluation is the key point for testing educational system. Since we were dealing with online classes and based on investigation on other researches, like Squires and Preece [20], Ardito et ell [21], Dringus and Cohen [22], Holzinger [23] and Achtemeier [24], we have used evaluation methods mostly depending on the object of evaluation, like evaluation of user-friendliness of the system, general impression, pedagogical effectiveness and effectiveness of each class.

5.1 SUMI Evaluation

The usability of the system was tested by 10 hard of hearing trainees. As per instructions in Software Usability Measurement Inventory (SUMI) [25] software documentation, a sample of 10 or more users per system being evaluated is required to get stable statistical results. Four participants were males and six of the participants were females. All participants had no basic computer and web browser experience before joining the e-course. The results of SUMI evaluation are shown in Figure 2. Data are presented in terms of the mean, the 95% upper and lower confidence levels (UCL and LCL). These descriptive statistics are given for the global usability scale and each of the five usability sub-scales (Efficiency, Affect, Helpfulness, Control, Learnability).

The global scale, the most reliable of all the SUMI scales, indicated that the usability of our user interface is comparable to successful commercial systems. In terms of the usability, sub-scales show that results are in general consistent, and nearly all fall within the desired range. The exception is a learnability sub-scale which

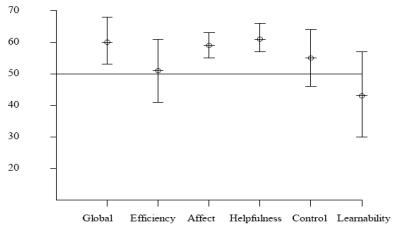


Fig. 2. Comparison of global and subscale usability scores (SUMI – evaluation)

falls under the desired range. Participants did not share the same opinion about application's efficiency, and had some problems with control of the application. Lower efficiency level shows that users may not always know what to do next or the software may sometimes work in a strange, inconsistent way. High helpfulness level on the other side shows that this application communicates clearly, users can understand the way it works and it gives them helpful hints and instructions.

The outcome of SUMI questionnaire confirms our statement, that the system is usable for integration into educational process. Detailed analysis of answers to questions leads to conclusion, that once the users overcame the initial difficulties with the system, they found the experience of working with it a relatively pleasant, with helpful support and reasonable performance.

5.2 Pedagogical Effectiveness

In the framework of total evaluation of the project, our aim was to evaluate pedagogical effectiveness of the classes. Chosen methodology is based on Sonwalkar method [26]. Sonwalker talks about Pedagogy Effectiveness Index (PEI), which consists of 3 dimensions (Media Types, Learning Styles in Interactions) that are further composed of several factors and this results in suitable probability distribution matrix.

Since our aim was to evaluate pedagogical effectiveness of classes for adults with special needs, we needed to adapt Sonwalker's probability matrix and the procedure. The result was new methodology for evaluation of PEI, which considers additional factors for people with special needs. We have added new aspect to learning styles, namely perception styles (visual, kinesthetic and audial), which matches different styles of impairment. In media styles, organization of material, in accordance with special needs, was added. Finally, a tutor was introduced into interaction, to receive feedback from students about the qualification of mentor to work with people with special needs.

The presence and good representation of each factor was evaluated by participants. Based on this evaluation, the PEI was calculated and it provided us with the information, whether the classes were pedagogically successful or not for the participants. 116 participants were involved, who were split into 5 age groups. 81 participants were females, 34 were males. Pedagogical index was calculated based on the equation, which returns a value between 0 and 1, whereas 1 is the best pedagogical effectiveness. The final result for all the participants was 0.68, meaning that participants were generally satisfied with the pedagogical work.

5.3 Course Effectiveness

In order to evaluate the efficiency of individual course, we implement pre-exam before the course where we tested the trainee for ones prior knowledge and post-exam, where the trainee took a final test after he finished the course. Each trainee had one week for learning each module. The pre-exam results were compared to post-exam results in order to establish how much did the trainees learn in one week. The results showed that trainees demonstrated very good response to using e-Learning materials. On the average they improved their knowledge for 25,5 % through all four modules.

The best results were obtained in practical modules (Word processing and Windows) where the average result on final exam was almost 80%. The trainees experienced some difficulties in theoretical module since the interpretation of many basic notions in sign language were very difficult. Therefore the average result was almost 70%. In all modules the gain of knowledge was significant.

6 Conclusions

Information and computing technology offers today the students effective support while learning, acquiring knowledge and communicating on several levels. Using ICT, teachers can provide necessary material for e-learning; furthermore they can effectively communicate with their students. Due to numerous advantages, e-Learning applications are suitable and successful also for education of people with special needs. However, the problem related to the development of such e-Learning applications is the variety of disturbances and impediments, which people with special needs are having, requesting more or less adapted execution of breeding and education with additional help, which can be either technical or of inter-personal nature.

In our work we have used adapted Course Management Systems Moodle for acquiring European Computer Driving License using e-materials for people with special needs In order to control the impact of e-Learning applications onto success of education. Additional functionalities, which show characteristics of e-Learning applications in the future, have been developed. For the analysis of needs and requirements and for setting the directives for development of e-Learning applications for everybody, including people with special needs, we have used analysis methodology for ICT projects defined by the European committee. The methodology included personal interviews with end-users, questionnaires and organization of discussion panels with brainstorming and feedback. For future user interfaces as well as for the materials, there has been general request for e-Learning applications to contain both accessibility and adaptivity, where there must be a strict distinction between these two terms. First of all, e-Learning material must be accessible taking into account physical, sensorial and mental capabilities of users. Furthermore, it presumes that the content is presented in a clear and simple way, and that simple, understandable navigation between the pages is used. In future-oriented adaptive e-Learning materials the e-Learning content can be adaptively changed according to user's capabilities and activities taking into account the pre-knowledge, learning curve, previous experiences with e-Learning materials, number of errors in

questionnaires and user profile, resp. type of disability. Our research work resulted with analysis that had given us some basic guidelines for creating effective adaptive and accessible e-Learning applications.

Conclusion can be made that future-oriented adaptive web based educational systems will include expert modules, student modules, tutoring modules and user interface module, all designed based on different criteria. In our work we designed basic adaptivity, in which system offers initiative and proposal; other activities were carried out by the user. For pedagogical and usability testing we have used evaluation methods mostly depending on the object of evaluation, such as evaluation of user-friendliness of the system, general impression and pedagogical effectiveness. SUMI evaluation was used for assessing the usability of the system. The outcome of SUMI questionnaire confirms that the system is usable for integration into educational process. We also evaluated the pedagogical and course effectiveness using appropriate methods; both were valued above the average. We can conclude that when planning and developing the next generation of future-oriented applications, accessibility and adaptivity of e-Learning materials must be considered as critical success factors.

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