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Improving Engineering Student Learning in a Web-based Learning Space Due to Virtual Reality Techniques and Advanced Interactivity

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Abstract

Information and communications technology (ICT) is changing the ways in which knowledge is being collected, processed, stored, presented and transmitted. Moreover, it is changing the ways in which course contents are presented and delivered to users. ICT appears to have the potential to individualize education and to provide it independent of time and location, improving its quality and efficiency in many aspects and shifting the emphasis on more cognitive questions. This trend requires a new analysis of the information and knowledge presentation in order to facilitate creating of an active learning situation and to support exploratory activities.

Dealing with this matter, the paper describes a beneficial virtual learning space for engineering educational activities. It points out the significance of shaping hypermedia contents with Virtual Reality components and interactivity features, which support the learner's imaginative and learning abilities, allow to freely move through the virtual world, to experiment with its elements, and to seek for further information.

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I. Introduction

Innovations in technology have changed the demands and expectations in the educational system. The expansion of the Internet has helped to address the user's need to access information and different services from all over the world at any time from anywhere. The new developments in networking will lead to high-bandwidth capabilities, which will be extended to the home. The timeline of this expansion is determined by cost and regulatory factors. Nevertheless, during the next years the network will become more universal and the increasing availability of interactive resources, distributed databases and information will systematically challenge the social life, and particularly the global education and training markets. The Internet will continue to play a leading role in the distribution of information and knowledge. Demographic factors and the current employment situation require that educational institutions adequately change educational programs and contents by increasing education's distributed accessibility. As education costs increase, students' needs for learner-beneficial courses, delivered in an appropriate way, with carefully designed contents will increase, too. The education market will establish the conditions for the rising competition and only the most valuable and strategic designed programs will succeed.

II. Weaving an Educational Web Strategy

The dissemination of knowledge is a main purpose of universities. Over the last several years, universities have been involved in the development and improvement of the Internet. This has enabled wide access to information and services. Thus, contemporary students expect a lot of services that save them time: online registration, online courses, online assessment, online digital library access, smart cards, etc. These demands led to the emergence of education portals, representing a Web site that provides organized access to the Internet through the offering of content and functionality by a personalized delivery of services. Consequently, an education portal optimizes the flexibility of a virtual learning space taking you directly and individually to various informational and instructional materials. Many universities are now developing education portals creating the basis for a global education market where local students could study for degrees or attend special continuing education courses. The main function of the education portals is to deliver just in time information and knowledge to users who are geographically dispersed or separated by physical distance from the instructors.

The education portals are shifting the emphasis on ICT environments in order to bring content and simultaneously context to the Web. An education portal offers users an immediate access to information and applications tailored to their educational needs and informational goals. It makes possible the access to information and services provided by various independent information sources or service providers. In consequence, a wide range of additional services must be integrated and implemented by the relevant service provider (purchase of software licenses, marketing of the application, competent help-desk assistance, security of the data and privacy of the users, etc.). The

technology infrastructure of the education portal is already a given fact. Now, users accept paying for the use of educational applications. In the education sector, subscription-based education portal services are a common approach. Frequently, these services are provided by third-party companies, or authorized education institutions with the intention that education institutions have the opportunity to lease or buy an access to applications, packages, or service tools.

An education portal may cover many scenarios for applications accessible through the Web site: Registration/Course enrollment; Virtual learning space; E-mail/Chat-room; Web search/ Full-text search; Access the library catalog/Purchase books; etc. According to different access levels users can obtain a personalized access to information related to them. For example, students can check their own examination marks, course schedules, library accounts.

Entering a virtual learning space, the quality of online university courses varies dramatically, which is one reason to acquire superior learning experience for developing effective courseware applications. A network infrastructure has, however, only to provide information and knowledge to students. Of course, numerous developments in hardware and software systems are required to exploit the bandwidth and make functionally rich applications usable by students and teachers. But technology alone does not solve any problem in presenting information and knowledge, or decrease cost, or increase quality of courseware applications. It is crucial to find the way in which technology can be best used to increase efficiency, effectiveness and quality of knowledge presentation in order to improve student learning.

Additionally, as systems become more complex and powerful regarding the applications they deliver and the volumes of data they can access and process, the need for effective help and navigation strategies becomes more crucial. Deficiencies in learning environments concern concepts, consistency, screen layout, interface design, navigation strategies, low-level of multimedia based interactions. In order to enlarge the communication capabilities in a learning environment, it is essential to focus on two fundamental aspects in the user interface: information presentation and information access. As ICT is used to provide the basis for improved communication and information sources to different users, these problems must be strongly considered in order to allow for the appropriate development of future systems and user interfaces, which also will extremely influence this area of the market.

Concluding, three major factors challenge the educational system: a competitive pressure for universities to acquire more students at lower costs, an adequate delivery system for courseware and services, and a constant consideration of user interface and knowledge presentation requirements. This disposition refers to the World Wide Web as a leading environment for future learning developments and calls for new strategies for interactive multimedia Web course applications and innovative university offerings. Recognizing these trends, they have been various projects addressed to the functionality of ICT in pioneering domains such as audio and video coding, automatic language translation, virtual reality. It is evident that there are clear implications for the higher education if the relevant developments can be viewed as improvement to the man-machine-interface. So the next section concentrates on Virtual Reality and its specific potential as a teaching and learning aid for 3D presentation as well as simulation purposes.

III. Advanced Information and Knowledge Presentation Techniques

Virtual Reality is a technology, based on 3D visual and increasingly 3D audio presentation, which can embody real-world or conceptual environments that can be navigated through and interacted with. The system responses are delivered in real-time.

There are many common applications for virtual reality categorized in the following manner: training (for example complex, expensive or dangerous experiments, flight simulations), education (for example visualization of hidden structures and objects, virtual laboratories, simulation) visualization (for example image reconstruction, architectural visualization, library databases), design (car shape, ergonomics), entertainment (virtual galleries and museums, games), and collaborative virtual environments for shared access.

Distinguishing between Virtual Reality delivering systems, there are immersive worlds (projection inside a CAVE or movement and tactile contact using headsets and data gloves) and non-immersive worlds (desktop Virtual Reality applications and tabletop applications). The use of immersive Virtual Reality in research work is already a fact. Concerning educational activities, the development of suitable and low-cost peripherals to provide tactile and visual input and feedback determines the timeline for the significant impact of immersive Virtual Reality in the teaching and learning process. Due to effective compressing techniques and therefore small file sizes the distribution of desktop Virtual Reality applications via the World Wide Web or on CD is unproblematic task. By installing only a free downloadable Plug-In (Cosmo Player, Blaxxun Contact, etc.) and appropriate programming, the applications provide an interactive access to the elements of the virtual world. The cost-effectiveness of non-immersive Virtual Reality applications and their clear support for the imaginative processes of different learners make them relevant to learning environments. Against this background, the further explanations concentrate on this type of Virtual Reality.

Virtual Reality applications already play an important part in the teaching and learning process but there is enormous potential for making more innovative use that can enhance the quality of teaching and add variety and excitement to the learning process. If the applications can be beneficially designed, they can

promote active and flexible learning and stimulate a deep approach to learning. Additionally, better selectivity and improved searching of the information can be implemented. A Virtual Reality world is effectively an interface paradigm that gives users some feeling of existence within an artificial world created by computer graphics [1] and can be designed to permit users control of some elements within that world. The navigation can be enhanced by the inclusion of active elements like icons or buttons. Adding text and/or VRML-animations, users' process of knowledge acquisition can be assisted.

An immense advantage of the presentation of non-immersive Virtual Reality applications is the opportunity to be integrated into a Web environment on HTML basis. At that moment, the capability to mix different media formats greatly enhances the ability to transmit information meaningfully. So developments in virtual reality technology could improve the effectiveness of the learning process even further. A well-designed multimedia package allows students to learn at their own pace and intensity according to their individual aims and conditions. Ensuring that the available knowledge is structured at appropriate levels of detail to meet the needs of different users, complex concepts can be supported by the immediate availability of interconnected granular presentations in various media formats.

Recent sociological studies have shown that the largest group of college students consists of concrete-active learners, who learn best from concrete experiences that engage their senses. The results of this important research must be a starting point for developers and institutions to customize their applications courses responding to diverse learning patterns [2]. Currently, only a small number of universities all over the world may have experts for preparing world-class applications and programs using in-house personnel and student design work. Enhancing World Wide Web developments, the new opportunities for interactivity and flexible access to various media challenge the traditional experience in shaping learning environments for online education. Here is a need to expand the cooperation between instructional designers, specialists in different disciplines, and media and communication technology specialists and to encourage communication across disciplines of effective pedagogical and graphical design.

The crux of the matter is the appropriate design of learning environments so the final application improves the motivation and the result, and beneficially supports the communication between author and learner. Therefore, the central problem focuses on the question of how knowledge could be purposefully represented regarding content transparency, and accessibility. Additionally, it concerns the development of a learning model that emphasizes the learner's active construction of concepts and knowledge rather than passive acquisition of factual data. Next section looks at particular aspects related to the creation of a beneficial learning environment as a key component of education portals.

IV. Composing a Beneficial Virtual Learning Space

The proposed framework for applying theoretical findings to engineering learning environments is illustrated with examples drawn from the virtual learning space Educational Media (Ed-Media) for real-time interactions, which is preferentially designed for university students in media engineering courses.

The virtual learning space Ed-Media puts the accent on the integration of effectively designed media elements targeted to the support of the learner's imaginative process. Showing internal constructions and functions in an impressive way, the developed 3D models of various objects can enhance the learner's needs for knowledge. The multiple presentations of the knowledge subjects facilitate the information acquisition and lead to advances in the learning process. The learning concept is intended for the adaptation of mandatory and optional subject matter in lecture courses. It concerns the content-based and graphical implementation of subjects by taking into consideration learner-beneficial aspects. Ed-Media is a complex learning space, which provides learning, communication, test, authoring, and content management facilities. The learning layer represents the fundamental part of the learning system. It enables an active as well an explorative learning.

The active learning mode covers functions aimed at the learner's effective and systematic interacting with the e-learning environment like history, thumb-tabs, footprinting, search, special form of fish eye views [3], annotations, etc. [4]. These user strategies offer a consequential opportunity for motivation-based self-controlling of the learner's own learning paths, dynamic self-regulating and content manipulating. They support the learner in solving navigation and orientation problems. Simultaneously, they facilitate the process of context abstraction. Novices often try to learn concepts in isolation from a context. The goal is to help the learner to become actively involved in learning so that he will be able to recall and apply the knowledge acquired. Defining a wide range of usable connections to a piece of information, it is easier to recall it.

The explorative learning mode offers the integration of plausible visualizations using mainly Virtual Reality worlds, which support the free investigation of complex contents, especially invisible or hidden processes and objects [5]. This kind of visualization allows a 3D time-based presentation of learning contents, which have not been visualized. The reality-closeness due to advanced modeling and texturing techniques as well the interactive access to varied contents increase the acceptance of 3D visualizations. The explorative learning mode stimulates the learning process accompanying the Virtual Reality worlds by additional information (text, static and dynamic illustrations), which is accessible in an individual way. Serving as 3D user interfaces, the Virtual Reality worlds enable the explorative learners to find their way in a naturalistic manner offering a precise

and complete interactive presentation of the subject matter (see also Section Enabling an Effective Learning Interface).

Figure 1 shows a screenshot of the explorative learning mode illustrating the virtual space of the flat membrane loudspeaker (on the right side), and the accompanying information as text and further visualisations (on the left side), which enhance the motivation as well the learning process.

The communication layer is a supplementary part of the virtual learning space. Corresponding to the main functions of an education portal, it has the potential to improve complex communication issues involved with users' admissions, clearance and statistical records. It manages the user registration process according to user rights and provides the access to the courseware library. Additionally, it supports synchronous and asynchronous communication among the learners (chat, discussion groups, e-mail, newsgroups, interactive pin-board, etc.) and with the tutor (for example individual bi-directional dissemination of tasks/projects, file upload and download, etc.).

Figure 2 shows a screenshot of the welcome site of the virtual learning space Ed-Media with a link to the courseware library, which can contain educational materials based on the learning strategy of Ed-Media and made with the appropriate authoring tool as well applications coming from other World Wide Web sources

Integrating synchronous and asynchronous communication, learning can be improved if the attention is being focused on the appropriate presentation of the material to be studied, on the required learner's interaction and the resultant interpretation of the material. In this case, the learning environment can enhance the learning process providing the feeling of having personal interaction with the tutor and other learners. By engaging the learner in important communication tasks, an active learning situation occurs.

The self-assessment layer ensures a reliable monitoring of the knowledge acquired in the different learning units, which are based on the learning strategy of Ed-Media. In the end of each module an interactive test session is made available. It contains questions completed as hot spots, hot objects, etc., and structured in different levels. Indicating knowledge deficiencies, the learner will be returned to the relevant topic where he can improve his competency. The reduction of knowledge deficit can also be achieved by use of the communication layer with access to the knowledge of the learning group and of the tutor respectively.

An important part of the development of learning environments is the support of authors' activities. According to user rights, students and teachers could act as authors managing content. The access to material offered in modular form and structured at

Figure 1. Screenshot of the explorative learning mode showing the structure of a flat membrane loudspeaker in an interactive manner (module *Sound Converter*).

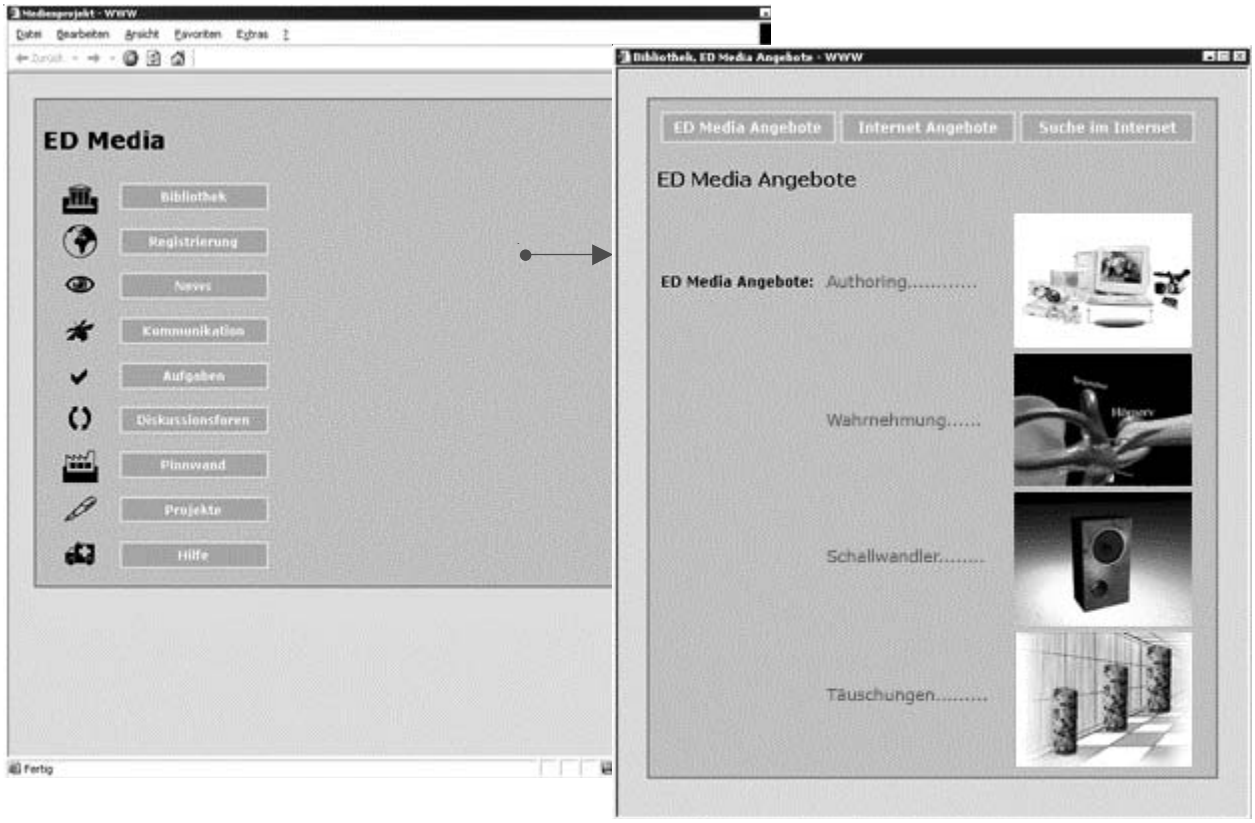

Figure 2. The virtual learning space with link to the courseware library.

appropriate levels of detail to meet the needs of different users enables the design of an effective content management system, which provides a customized access to different parts of the courseware stored in the courseware library. Authors are able to select those elements that are relevant to their own needs and put together a personalized content in the established user interface of Ed-Media. As a result, new contents can be quickly and conveniently created by re-use of the text, visualization and audio files, which are available in the database, as well their adaptation to a personal view, or by adding new information.

While this section provided the framework for generating and offering educational contents in a virtual learning space, the next section will focus on content presentation features. The enhancement of the students' learning activities can be managed by a suitable knowledge presentation, which should enable better understanding of complex objects or complicated relationships.

V. Enabling an Effective Learning Interface

In learning systems, the precise decision on integration of interaction opportunities and the proper goal-oriented selection of media formats for content presentation are the cruces of the matter. The solution of the dilemma is designing a beneficial user interface that should enhance the individual motivation and serve the communication between author and learner most advantageously. Frey and Soloway [6] state that the user interface is particularly important for educational software because it must provide an entry to the content domain and it must be sensitive to the general skill and developmental level of the user.

Shaping Web-based learning environments with Virtual Reality components shifts the emphasis on the 3D user interface concept, which becomes important in facilitating the learner's reality-close imagination. The access to numerous interactivity features as well metaphors, subdivided by Kloss et al. [7] into navigation (autonomous change of the position in the Virtual Reality world), manipulation (direct object manipulation), activation, request (information request related to particular objects or their linkages), and presentation (dynamic rendering of the Virtual Reality world) enables the learner to select the situation-relevant information and to execute the autonomous movement through the learning space.

Compared to conventional 2D learning environments, the navigation and menu construct of 3D learning environments can be shaped more effectively. In the explorative learning mode of the virtual learning space Ed-Media, the learner has a concurrent access to the visualised complex 3D objects as a menu. This

specific detail helps the learner in handling, addressing and exploring the particular menus, which guide to sub-domains of the entire structure. Trying to map the same structure into a 2D environment, one dimension will be missing for presentation of the equivalent detailed menu structure. The particular media elements (text information, static and dynamic illustrations, Virtual Reality worlds, and Virtual Reality animations) can separately be activated allowing for an individual learning situation [5]. The learner has the opportunity to interact with a particular media element or with a preferred composition of media elements.

VI. Conclusion: Vision on Education

The paper has shown that a highly interconnected and powerful network of computing, information and knowledge resources is emerging through the use of information technologies providing students and teacher with individualized access across institutional and national borders. The vision should consider the potential of technology but the question is how universities can exploit technology to provide the most learner-beneficial as well as cost-effectively designed learning content. Sociological studies point to the learners' preferences of the real-time aspect compared with the quality aspect. Long loading time and inadequate interactivity options cause a decreasing user acceptance. The availability of multimedia and Virtual Reality techniques with simulation features initiates a new appearance for learning applications - real-time presentation of 3D data. Real-time presentation of 3D data requires high quality and performance for hard- and software. Nevertheless, its relevance is progressively rising in learning environments. Learners attach great importance to most possible authentic event experience and to high-grade real movement in the learning space.

The vision is of a networked society with shared access to knowledge and information, especially in three dimensions. It requires prompt political decisions regarding access to and regulation of telecommunications networks, copyright law, funding of suitable educational materials, and high-speed networks. The problem is that is a lack in financial supporting the need for new learning environments, which integrate distributed applications and educational software with multiple media presentations.

In summary, the higher education sector of the next decade will be subject to considerable change. There will be a competition for funds and students. Students will be more demanding and will require flexible educational programs. The university of the future will be closely integrated into the local and regional community and often with an international dimension. The last vision is confirmed by the integration of the described virtual learning space Ed-Media into the thematic network Thematic Homogeneity in Electrical and Information Engineering thanks to pre-Requisites and ECTS, which is intended by the European Association for Education in Electrical and Information Engineering and funded by the European Union. About eighty European universities participate in this network that allows students to access a cross European distance education.

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