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Virtual Universities in Engineering Education*

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Computer and telecommunications technologies are having profound effects on higher education. They influence whom we teach as well as how we teach. Indeed, the appearance of 'virtual universities' reflects new developments with respect to who is doing the teaching. This special issue of the International Journal of Engineering Education examines the role of virtual universities in engineering education. In this introduction to the issue, we first consider two challenges to traditional higher education and suggest that 'virtualization' is one way to respond to these challenges. We then define and describe what we mean by 'virtual university'. We outline the many issues raised by this form of education for engineers and other learners and provide an overview of the papers incorporated in this journal. Finally, drawing some conclusions from the papers and from our own experience, we express some thoughts on what the future might hold for the 'traditional' engineering schools and for learners seeking access to engineering education.

INTRODUCTION

COMPUTER and telecommunications technologies are having profound effects on higher education. They influence whom we teach as well as how we teach. Indeed, the appearance of 'virtual universities' reflects new developments with respect to who is doing the teaching. Book publishers and other for-profit organizations have adopted these technologies to compete directly with the 'traditional' institutions of higher education.

This special issue of the *International Journal of Engineering Education* examines the role of virtual universities in engineering education. Perhaps because engineering is intimately related to the computer and telecommunications technologies, it has been among the disciplines first and most deeply affected by them. Another reason has been the escalating demand for continuing education for engineers by high technology industries anxious to foster means for keeping their engineering workforce technically up-to-date.

In this introductory article, we first consider two challenges to traditional higher education and suggest that 'virtualization' is one way to respond to these challenges. We then define and describe what we mean by 'virtual university'. Next we outline the many issues raised by this form of education for engineers and others. We provide an overview of the papers incorporated in the journal. And finally, drawing some conclusions from the papers and from our own experience, we express some thoughts on what the future might hold for the traditional engineering schools and for learners seeking access to engineering education.

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CHALLENGES TO CONTEMPORARY HIGHER EDUCATION

Higher education is today facing two major challenges. First, there is a shift from a supply-oriented view to a demand-oriented view. For example, the crucial question has become not how to improve teaching but how to improve learning. Moreover, there is increasing demand for new knowledge and skills. The amount of information that needs to be learned is growing rapidly—and often becomes obsolete just as quickly. Life-long learning is the buzzword. At the same time businesses and other organizations are becoming geographically dispersed and networked. This is also true for educational institutions. Universities cooperate with companies, other universities and research labs to produce 'content,' i.e. learning material. On the other hand students are becoming more mobile and geographically dispersed, too. They can be seen as customers in the emerging education market with the right to choose and to get education from suppliers that are remote. Often, it becomes not only physically but also financially impractical to bring learners together in a 'real' classroom.

Second, new technologies are transforming the methods of teaching and learning. They are reshaping the expectations, needs, and opportunities in education. The basic information technology tools for transforming education are already available. Access to learning resources is easy via the Internet. Distributed collaboration using electronic media is a reality. The World Wide Web and communications technologies create unprecedented flexibility in time, location, content, and form of instruction. Students are potentially able to learn what they need when and where they want to and in the format most appropriate to their needs [1, p. 52]. The implications of these technological developments and the demand-oriented requirements are producing a paradigm shift in teaching and learning. Universities have to cope with this trend. They have to adapt to new technological environments and possibilities as well as to new organizational structures. They must develop a solid basis for a new flexibility in education and expect to exploit this basis as a success factor for competing in regional, national, and global education markets.

'Virtualization', or creation of a virtual university, is a technology-intensive approach to dealing with these challenges in university education. So what is a *virtual university*?

CHARACTERIZING A VIRTUAL UNIVERSITY

'Virtual university' is a term used to cover an extremely broad range of educational situations. Other terms used synonymously are 'virtual college', 'virtual campus', and variations of these terms in which 'virtual' is replaced either by 'on-line' or 'digital'.

The word 'virtual' stems from the Latin word 'virtualis', later 'virtuel' in French, and can take on the meaning of 'potential', something that is not real but possible. A virtual object is a representation of a real object, with the same characterizing properties. In this sense the virtual object exists, but it is not tangible like the real one.

Following this interpretation, a *virtual university* is an electronic representation of the features of a real university. The features exist on computers or are provided with the help of information and communications technologies. They exist but are not physically tangible. You do not go to a virtual university on foot but electronically. The learning space is based on a network of computers. There is perhaps a virtual campus you can 'see and feel' on a computer screen. There are teachers and students you cannot touch but can interact with electronically. There is learning material you may not hold in your hands and carry away but you can nonetheless experience it electronically anytime and anyplace.

The usage of electronic media increases the flexibility in time, location and content. In this way terms like 'distance education,' 'tele-teaching,' 'tele-learning,' 'e-learning,' 'digital lectures,' 'on-line courses,' etc., belong to the scenario of a virtual university. Today, the basic infrastructure and global foundation for connecting and interacting with a virtual university are the Internet and World Wide Web.

Very few of the institutions that use these terms to describe themselves mirror what traditionally is viewed as a university, i.e., 'an institution of higher learning providing facilities for teaching and research and authorized to grant academic degrees' [2]. Granted, there are many such institutions that provide technology-based facilities for instruction and offer academic degrees. There are others that provide the facilities for instruction but do not offer degrees. Still others offer degrees, but do not themselves provide facilities for instruction. However, almost none have an interest in research except, perhaps, research on the effectiveness of their instructional programs and methods.

It serves no purpose to quibble over the terminology. All of these scenarios are of interest here to the extent that they involve the use of computer and/or telecommunications technologies to enhance access to engineering education for persons that are remote from higher education institutions, are physically handicapped, or are simply too busy to return to the traditional campus setting. In addition to enhancing access, skillful use of the technologies often results in improved teaching and learning, may make available otherwise inaccessible expertise and content materials, and may better serve the needs of persons with diverse learning styles.

ESTABLISHING A VIRTUAL UNIVERSITY

Virtual universities have been established in a variety of ways; for example:

- Building a virtual university 'from scratch,' i.e., a virtual university is founded, as a completely virtual institution, by an existing traditional university or by the state. Example: The Western Governors University in the United States [3].
- Founding a completely virtual university as a joint venture by several co-operating universities. Example: The Virtual University of the Upper Rhine Valley, described in this issue by Kandzia and Ottman [4].
- Developing and integrating virtual learning resources/courses/studies in an existing university setting. Example: The British Open University [5] and the University of Hagen described in this issue by Kaderali et al. [6].
- Outsourcing educational departments of a company as a profit center ('corporate universities'). Example: Motorola University [7].
- Forming university networks, either to counter competition from other virtual universities or simply to enhance access to higher education for underserved populations. Example: The Indiana College Network in the United States [8].
- Building international education consortiums, which may include both content providers,

such as universities and book publishers, and information technology organizations such as television and cable companies, Internet service providers and other communication media companies. Example: Universal consortium of the European Union [9].

Universities worldwide, large and small, have adopted distance learning as a strategic initiative for maintaining or enlarging their share of the engineering education market. Because the cost tends to be rather high, regardless of the medium or media employed, many maximize the return on their investment by focusing on market niches where the demand is acute and their engineering faculty is especially strong.

Were we to attempt to provide a comprehensive list of virtual universities offering engineering subjects, serious omissions would be inevitable. The list is growing month by month. The articles in this issue represent a small but diverse sample of such institutions.

ORGANIZING A VIRTUAL UNIVERSITY

The architecture of a virtual university has both organizational and technical aspects. Most of the academic and administrative support services that are part of the traditional university must be implemented in the virtual university. Many of these must be adapted to be effective in the virtual environment, usually by employing computer and telecommunications technologies. For example, students may register for their courses using touch-tone telephone, facsimile transmission, or the World Wide Web. Because of the convenience they provide, the demand for such electronically provided self-service functions is growing even on traditional campuses.

Just as the students in a virtual university are geographically distributed, so may be the content providers. Courses can be developed following a building-block approach; a course may be constructed by integrating modules created by different providers, some of the modules may consist of sub-modules delivered by other suppliers, and so on. This leads to production management much like supply chain management.

Moreover, courses implemented electronically may be customized, i.e., tailored to the needs and preferences of a target group of learners or many individual learners. This education brokerage service may be combined with pedagogical or tutorial assistance. The next logical step is comprehensive 'learner care,' analogous to the customer-relationship management approach in e-business.

There are many more challenges to be met in a virtual university, such as providing for 'virtual exams.' Many of these are mentioned in the articles in this issue.

The technical architecture consists of an information technology infrastructure, telecommunications and various support systems. On the server side a content storage and management system is needed. A common approach is to create a multimedia-oriented repository for learning resources. Here, one challenge is to develop a metadata scheme or framework for retrieval purposes. Another challenge is to link existing external services to the architecture, e.g., digital libraries or electronic billing and payment systems. Content delivery often requires technical support at the learner's side. Usually the virtual university provides a website hosting an access system that is in charge of security mechanisms such as authentication procedures. After being identified as an authorized user, the student may walk 'virtually' through the electronic campus, get information about current on-line courses, use teaching materials corresponding to his or her studies, and communicate with teachers, tutors, and other students. Homework, exercises, seminar papers, etc. are done on the student's computer and the results submitted by e-mail. Electronic feedback mechanisms are a very important feature to help navigate through a course of study without getting lost in the university's cyberspace.

To illustrate some features of a portal, or entry point, for the virtual university, the concept of the Fernuniversitaet Hagen (Open University of Hagen) in Germany is outlined [10].

The technical basis is a client/server system consisting of World Wide Web servers, database servers, videoconference servers, and other communication servers. The servers offer general information about the institution, learning material for all kinds of courses, and communication and collaboration channels. On the learner's side a PC is needed equipped with a low-cost video camera and microphone, a common Internet browser, and some plug-ins for Internet-based audio- and videoconferencing.

Entering the WWW portal, icons, menus and pictures depict the virtual environment. The Information Menu contains general information about the university and its staff, with guided tours through the virtual campus as well as a help desk. The Education Menu offers courses, seminars, tutorials, and exercises. The News Menu provides access to a bulletin board system containing a variety of up-to-date information. The Virtual Cafeteria offers a forum to promote social contacts among students using e-mail, chat, newsgroup and other tools. The Virtual Library provides access to both traditional and digital libraries. An Electronic Shop offers all materials and products that can be purchased from the university, including learning materials. In the Research Area it is possible to contact researchers and research students and retrieve project reports, research papers, and scientific information. The Office Component includes all administrative functions such as student registration and course enrollment.

MEDIA EMPLOYED

Virtual universities are strongly characterized by the principal medium or media they use to deliver courses. Media are used both for content delivery and to support instructor-to-learner and learner-to-learner interactions. The location, dispersion and size of the audience influence media selection. The cost and the effort required to prepare, deliver and update course materials vary significantly according to the media selected.

Television was the first medium to be used for content delivery and, in its many forms, is still a highly cost-effective means of delivering educational programs to widely dispersed audiences of practicing engineers. Transmission by land-based microwave and by satellite is used for this purpose; videotapes are also popular.

Today, as video and computer technologies converge, the Internet is widely seen as the future medium for transmission of multimedia subject matter. The term 'multimedia' encompasses a wide variety of methods for representing and transmitting information in the virtual university. Although printed text is still widely used and cost-effective, more typically electronic handouts, work sheets, articles, and even complete electronic books are placed in digital form on the Internet. In addition to text, these documents may contain diagrams, pictures, and calculations. Graphical materials and audio or even video may be combined by multimedia editors and stored on video servers to provide the equivalent of classroom lectures transmitted via the Internet. Servers can also store software demonstrations, simulations and didactic games ('edutainment'). Tutoring systems may include interactive components such as quizzes and tests. There are also special scenarios to promote interaction and learning by discovery; examples are virtual laboratories and other virtual domains.

Of course, all kinds of multimedia learning material can be networked using the hyperlink concept of the World Wide Web. Rich learning environments can be created to accommodate a wide range of learning styles and may lessen the impact of many forms of disabilities that impede learning.

In these virtual courses, communication is a critical factor, not only between tutors and learners, but also among the learners themselves. Students contact other students for a great variety of reasons; e.g., for help with technical and learning problems, to share studying experiences, and for social purposes. There is a wide spectrum of support tools to enhance communication, interaction, and information sharing: e-mail, chat rooms, discussion groups, news forums, video/audio conferences, whiteboard applications, co-authoring and application-sharing systems.

COMMON CRITICISMS OF VIRTUAL UNIVERSITIES

Although in a well-implemented virtual university it is possible to get electronically in touch with teachers, tutors, and students whom one would not personally meet in a lifetime or certainly not very often, many critics point to the risks of reduced social contact in this environment. Indeed, the danger of de-personalizing the teacher/learner interaction may lead to a lack of discipline on the learner's side and, possibly, on the teacher's side as well. Carried to the possible extreme, the anonymous learner and teacher is a horror vision, especially from a pedagogical and psychological standpoint.

Another criticism of the virtual university is the sophisticated technical equipment often required. In this environment, there are risks of malfunctions of the learner's computer, software errors, server shutdowns and communication breakdowns. The users (learners and teachers) have to accumulate hardware and software know-how to be able to act and react 'virtually.' And not to be overlooked: The equipment may be costly. A considerable amount of money has to be invested in the information technology infrastructure and software. This is true both for the virtual university itself and also for the student required to work with multimedia resources. Also, communication costs may be a high hurdle. For example, in Germany and other European countries, communication costs are considerably higher than in the US and flat rates for Internet usage are still widely unknown.

Critics also note that often neglected by purveyors of virtual education are the pedagogical and didactical strategies needed to suitably complement the instructional usage of electronic media in general and distance education in particular. Too often, creators of media-based courseware simply attempt awkwardly to emulate the traditional lecture-based classroom by replacing the lecture with text. The teacher/learner and learner/learner interactions known to enhance learning may be poorly attended to at best. There may be little or no attempt to capitalize on the dynamic and colorful properties of the media that can also enhance learning.

While these are valid criticisms in general, the papers in this issue demonstrate an awareness of the possible shortcomings and efforts to overcome them in the modern virtual universities.

OVERVIEW OF THIS ISSUE OF IJEE

The papers in this special issue of the *International Journal of Engineering Education* cover a wide spectrum of topics related to virtual universities and engineering education.

The first three papers broadly describe full-scale *implementations.* Baldwin and Johnson depict in detail the development and operation of the National Technological University in the United States. NTU is now a mature distance learning institution offering its own master's degrees based on coursework provided by a consortium of major US engineering schools.

Kaderali et al. describe how the University of Hagen, a German University created in 1974 specifically to provide distance education, is now adopting Internet-based procedures to enable them to become truly a full-service virtual university. Its faculty is finding that these procedures help eliminate 'the gap between (distance education) teachers and students due to the geographical distance between both parties'.

Winer et al. relate the efforts at a single institution, the Georgia Institute of Technology, to deliver, via the Internet, graduate education leading to the Master of Science in Mechanical Engineering. Georgia Tech uses a well-developed off-the-shelf courseware package and digital compression to enhance the Web-based delivery of multimedia courses to a student body that collectively may be employing a wide range of modems and personal computers.

The next two papers look more closely at some of the *foundational principles*—societal, pedagogical and technological—that must be taken into account in the development of any virtual approach to teaching and learning. Kandzia and Ottmann are involved in a 5-year project, under way since 1998, in which four German universities and a number of commercial institutions are collaborating to create 'The Virtual University in the Upper Rhine Valley'. The project has four components: content building, technology, evaluation, and organizational issues. In the next paper, Wheeler and Vranch provide a framework for evaluating alternative technologies in the roles required by a virtual university.

The final six papers describe specific components or *tools* used to implement and enhance the virtual teaching and learning environment. In the paper by Geyer-Schulz et al., the virtual university is characterized as 'an information market.' The authors describe research on 'recommender systems', which they suggest can be employed to free teachers from routine, time-consuming tasks and generally to enhance the interfaces among teachers, learners and educational resources.

Papers by Huang et al. and Ridwan et al. deal with the features that must be implemented in a 'courseware engine' in order to provide rich teaching/learning environments. Specifically, Huang and his colleagues are concerned about supporting active, collaborative problem-based teaching and learning; Ridwan et al. illustrate the application of their courseware model to a thermodynamics and heat transfer course taught using a variety of media. Sclater et al. then focus even more closely on how the Internet can be exploited to enable students to work effectively together at a distance on collaborative design projects.

As Kapadia et al. point out, modeling, simulation and computer-aided design are integral components of the modern practice of engineering. The final papers, by Spedding and by Kapadia et al., deal with approaches through which the specialized hardware and software required to teach and utilize these technologies can be made available in a highly effective manner via computer networking.

LOOKING TO THE FUTURE

The potential benefits of the new electronic model of education called 'virtual university' go even beyond more convenient access to education (flexibility of time, place, content, and pace). This approach will dramatically alter the cost structure of education. By analogy to other digitally represented products such as software, videos, music or financial services, the marginal costs of mass production and delivery of electronic education are quite small. Thus, there is great potential for economies of scale. In addition, with the support of brokerage and composer systems the educational products can be tailored to the learner's needs. These effects taken together are known in e-business as mass customization. These developments portend benefits both to the education industry and the consumer.

Virtual universities are vying, and will do so with increasing intensity, with traditional universities and other educational organizations, both public and private, for a significant share of the promising media-based education market. Supporting the convergence of supply and demand electronically in this context is truly challenging. An 'electronic market' [11] for education and training is emerging to support the exchange of goods and services by applying market-oriented mechanisms. 'The market is not a place, a thing or a collective entity. The market is a process, actuated by the interplay of the actions of the various individuals' [12]. One can expect that developments in electronic commerce [13] will increasingly shape the establishment of an electronic education market [1]. Virtual universities will play an important role as certified content providers as well as technical service providers for electronic learning. The field of engineering education will continue to provide strong leadership.

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