Adaptive e-Learning Environment Design

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Summary

Virtual Learning Environments and Adaptive Learning Systems correspond to distance learning solutions that seek to meet the promise of individualized learning.

Technological innovation, nevertheless, is not sufficient to ensure high learning outcomes. While the number of distance learning packages multiply in the market, it is important to consider their pedagogical use, instead of focusing on listing and describing their features.

Catering for diversity in learners is also not enough for the design of quality solutions that can efficiently support the learning process. It is necessary to acquire knowledge regarding individuals' different and real learning needs, through a human-centered design process. That is the challenge for designers of e-learning environments and materials.

Keywords: Distance education, e-learning, Virtual Learning Environments, Adaptive Learning Systems, multimodal interaction

Introduction

The information and communication technologies revolution has continuously transformed life in society, bringing new demands, as well as novel expectations concerning education, such as convenient flexibility in time, location and structure. The population of learners that seek on-line alternatives to the traditional classroom is the fastest growing sector of the educational marketplace. And, according to the predictions of the U.S. National Center for Education Statistics report, the number of online learners will increase from 3 million in 2001 to more than 6 million by 2006 (National Center for Education Statistics, 2003).

The promise of individualized learning, however, cannot be achieved using traditional approaches, especially at large scale, due to the diversity among learners, the disparities in access to media and the plurality of the contexts of use of technology.

Virtual Learning Environments and Adaptive Learning Systems are some of the distance learning solutions that seek to meet those needs by synthesizing the functionality of computer-mediated communications software, and by providing an interface capable of

automatically tailoring itself initially to each user and of coping with the dynamically changing and emerging user requirements during interaction.

Technology alone, however, is not sufficient to ensure that learning takes place. Frequently, the analysis of distance learning packages is limited to a list of features and system capabilities. It is essential to consider the pedagogical use of such instruments and to account for the diversity in learners' needs throughout the design process.

This paper is divided into five main sections, including this introduction: Virtual Learning Environments and Adaptive Learning Systems, conclusion, references, and acknowledgements.

Virtual Learning Environments And Adaptive Learning Systems

The terms distance education, distance learning and remote learning have been applied interchangeably by many different researchers to a great variety of programs, providers, audiences and media. According to Sherry (1996), its hallmarks are: the separation of teacher and learners in space and/or time, the volitional control of learning by the student rather than the distant instructor, and non-contiguous communication between student and teacher, mediated by print or some form of technology. Virtual Learning Environments, VLEs, correspond to one such technology that can mediate this process, together with Adaptive Learning Systems, Adaptive Learning Environments (ALEs) or Adaptive e-Learning Environments.

Research in distance education has tended to follow similar trends to research with other new technologies. Studies have explored learner outcomes, trying to prove, eventually, that the use of the new delivery systems would result in higher student achievement (Silver, Hanson, Strong & Schwartz, 1996; Russel, 1999; Saba, 2000). Some of them have shown that distance education is at least as effective as traditional education with regard to learner outcomes. In spite of the results that state there is no significant difference in achievement attributable to the delivery system, according to Maushak, Chen, Martin, Shaw & Unfred (2001), they correspond to a very narrow sampling of what research is being conducted in the field of distance education.

Diaz (2000) explains that much of the research from the 1980s and 1990s, which considered distance education effective, demonstrated weak research design, specifically in relation to control of the populations being compared. Phipps & Merisotis (1999) suggested that the design flaws in distance education research have made the research results inconclusive.

Too often, researchers and developers, being enamored of the latest technologies, fail to deal with the underlying issues, such as learner characteristics and needs, the influence of media upon the instructional and learning processes, equity of access to interactive delivery systems, and the new roles of teacher, system administrator and students in distance learning process.

Virtual Learning Environments, VLEs, are learning management software systems that synthesize the functionality of computer-mediated communications software (e-mail, bulletin boards, newsgroups etc.) and on-line methods of delivering course materials (like the World

Wide Web). VLEs or Electronic Learning Solutions (e-Learning Solutions) include a set of tools that facilitate the creation and management of Web-based educational environments. They are used in education to support the teaching and learning processes in various ways, and, increasingly, to support on-line distance learning. According to Britain and Liber (2000), the benefits of VLEs are: flexible time and place; coping with increased student members; sharing and re-use of resources; enhancing collaborative work; supporting student-centered learning; reducing the administrative burden; increasing staff development; and supporting time-intensive learning styles (Moura, 2005a and Moura, 2005b).

Nowadays, there are over one hundred packages available on the market (Essaka, 2001; Landon, 2000), developed by universities or commercial companies. The common features of these packages are: synchronous and asynchronous communication tools, an interface that allows the design and uploading of course material, administrative tools, evaluation tools and student tools. A more detailed description of these packages is provided on Table 6 (Britain and Liber, 2000).

Some issues associated with VLEs are: authentication, importation and adaptation of existing materials, standardization, support to main teaching and learning activities, robustness, requirements for course designers, requirements for server set-up, costs, security, access rights, ease of use and set up, and customization to house style.

Britain and Liber (2000) offer a framework for pedagogical evaluation of VLEs. Unlike several other research papers on the area, which list and compare different features of environments' systems, the referred authors consider their pedagogical use.

Table 6: VLE System Features	
Synchronous and asynchronous communication	Discussion forums, internal and external e-mail, IRC (Internet Relay Chat), one-/two-/multi-point video conferencing, web browsing, notice boards, bulletin boards (or notice board that supports discussion), whiteboard (or notepad), online journal and file exchange.
Productivity tools	Bookmarks, calendar, scheduling and progress review, orientation, on-line help, searching within course, working offline and synchronizing.
Student involvement tools	Collaborative projects, self-assessment, student community building, student portfolios and homepages.
Administration tools	Authentication, course authorization, hosted services, registration integration.
Course delivery tools	Automated testing and scoring, course management, instructor helpdesk, online grading tools, student tracking, progress tracking.
Curriculum design tools	Accessibility compliance, content sharing and reuse, course templates, curriculum management, customized layout, instructional design tools, instructional standards compliance.

The referred authors consider how to evaluate the properties, capabilities and orientation of different systems, based on the conversational model proposed by Laurillard (1993), the Viable System Model, VSM, (Beer, 1981) and some pedagogical criteria (Table 7).

Table 7: An evaluation framework for VLEs using the conversational model

Activity	Tools	Structuring
1. Teacher Presents Conception	What tools does the teacher have to hand: Text, video, audio, images?	Can a teacher easily put together different multimedia formats for presentation of a conception? Can these be readily altered for representation in a different way.
2. Student Presents Conception	Can the student interact with the teacher through the system? Does the student have multimedia authoring capabilities? Even if text-only, how does the student communicate with the teacher?	Clearly the dialogue between student and teacher is at the center of the conversational model and how this is visually structured for both tutor and student is very important. Conversations should be at the center of activity in the VLE rather than pushed to one side.
3. Teacher sets up micro world	Multimedia authoring tools for creating course materials, embedded or linkable simulation programs, testing software such as quiz creation programs etc.	In a VLE the notion of micro-world can be applied at many different levels. The important point from the perspective of the conversational model is that it should be versatile enough to be adapted for an individual student on the basis of the ongoing conversational dialogue with that student.
4. Student interacts with micro world	See 3 above	Again we can see this notion of micro-world at various levels. We are looking for more from the student side than simply being able to view content.
5. Tutor provides feedback to the student	Can the tutor use the communications tools to provide feedback to the student in the context of the students' activities?	It might seem obvious that this would be true but the important point is that the feedback can be easily related to the action - i.e. any discussion thread should be linked to or embedded in the domain of actions.
6. Student modifies actions	Can the student return to the activities and modify their actions based on feedback received from the tutor?	

The conversational model focuses on interactions between an individual student and tutor. An evaluation from this perspective helps to identify whether a VLE is set up to allow individualized activities to be constructed for a student. The activity should be based on a prior discussion with the student that has identified any mismatch in the conceptual domain between tutor and student and the VLE should support this process.

The VSM model focuses on how the software helps a tutor manage conversations and the construction of individualized activities for a large number of students. In order for a VLE to effectively support the tutor in doing so, it must not only be easy to adapt on the fly but also provide for student self-organization, resource gathering and publication of material to the system.

A new conceptual trend among technologies that can mediate non-contiguous communication between student and teacher is called adaptive systems. Currently, several systems employ adaptive techniques to enable or facilitate different aspects of learning (Brusilovsky, 1999; Paramythis & Loidl-Reisinger, 2003). ALE, Adaptive Learning Environments or Adaptive e-Learning Environments, is one of these.

The potential of adaptivity in e-Learning has, in recent years, received heightened awareness. This occurred, mainly, due to the realization that the ideal of individualized learning cannot be achieved using traditional approaches, especially at large scale. Additionally, the diversity among learners, the disparities in access to media and the plurality of the contexts of use of these technologies have contributed to this approach.

Adaptation and adaptive systems, however, is not a new field of research. According to Andrews, Barrios, Gütl, Mödritscher, Pivec, Preis & Trummer (2004), it goes back to the 1960's, with the proposal of Systems Theory by Ashby (1964).

Adaptation refers to both the process of adapting and the condition being adapted. The term adaptive is currently being associated with a wide range of system characteristics and capabilities. Different types of adaptation can be identified: anticipatory or reactive, autonomous or planned, generic and selective.

Savidis, Paramythis, Akoumianakis & Stephanidis (1997) proposes that the run-time interface transformation process in user-adapted interaction can be seen as a combination of two complementary classes of actions initiated by the system: adaptation decisions starting from the initial knowledge of user attribute values, available at start-up - i.e. what the server knows regarding the user prior to interaction, and adaptation decisions that occur due to knowledge of user attribute values inferred during interaction - i.e. assumptions made from user information by the server based on interaction monitoring information. The first behavior is known as adaptability, and reflects the capability of the interface to automatically tailor itself initially to each user. The second behavior is called adaptivity, and refers to the capability of the interface to cope with dynamically changing and emerging user requirements during interaction.

A learning environment is considered adaptive if it is capable of: monitoring its users activities; interpreting these activities on the basis of domain-specific models; inferring user requirements and preferences from the interpreted activities, as well as representing these in associated models; and acting upon the available knowledge regarding its users and the subject matter to dynamically facilitate the learning process (Paramythis & Loidl-Reisinger, 2003).

Adaptive e-learning is not a new research field either. It goes back all the way to Plato, or, in the 1950's, to Skinner (Andrews, Barrios, Gütl, Mödritscher, Pivec, Preis & Trummer, 2004).

Examples of Adaptive Learning Environments are: ELM ART (Brusilovsky, Schwartz & Weber, 1996), AHA (De Bra & Calvi, 1998), INTERBOOK (Brusilovsky, Eklund, & Schwarz, 1998), KBS Hyperbook (Henze & Nejdl, 1999), TANGOW (Carro, Pulido & Rodriguez 1999), KOD (Karagiannidis, Sampson & Cardinali 2001), OPAL (Conlan, Dagger & Wade, 2002), OLO (Rodriguez, Chen, Shi & Shang, 2002), HyCo Hypermedia Composer (Berlanga & García, 2004), and AdeLE (Andrews, Barrios, Gütl, Mödritscher, Pivec, Preis & Trummer, 2004). OPAL delivers content personalized to the learner's cognitive and presentation learning preferences. AdeLE framework provides a User-Adapting System, or UAS, that adapts to user traits/characteristics and states.

Adaptive e-learning systems support adjustment regarding the characteristics of the learner. Rumetshofer & Wöß (2003) affirm that, in learning systems, adaptation is two-fold: what can be adapted in such environments, and how the presented psychological factors influence the adaptation. Brusilovsky (2001) states that there are three kinds of adaptation in hypermedia systems: content, layout and navigation.

Content adaptation in learning systems depends on a student's preferences and personal skills, thus produces an optimal curriculum sequence. Layout needs to take cognitive overload into consideration, as well as learning styles. Navigation adaptation in learning systems is influenced by learning sequences, which describe the order and organization of learning activities. Here, learning styles, once again, seem to be responsible for determining an individual's request for a kind of sequence. For example, analytical learners prefer to learn in a sequential manner, while random learners like to choose their own course of interaction (Moura, 2005a).

According to Andrews, Barrios, Gütl, Mödritscher, Pivec, Preis & Trummer (2004), some critical questions in the context of adaptive e-learning are: what has to be adapted and how, how can the student's behavior be monitored in the best way, and how can the system automatically adapt to the student. Paramythis & Loidl-Reisinger (2003) emphasize that adaptive behavior on the part of a learning environment can have numerous manifestations. The authors offer a high-level categorization for analysis. The partially overlapping categories are: adaptive interaction, adaptive course delivery, content discovery and assembly, and adaptive collaboration support. The first category refers to adaptations that take place at the system's interface and are intended to facilitate or support the user's interaction with the system, without modifying the learning content. The second category, adaptive course delivery, refers to adaptations that are intended to tailor a course or a series of courses to individual learner characteristics, so that optimal learning can result. It is the most common adaptation technique applied, nowadays, in learning environments. The third category, content discovery and assembly, is related to the application of adaptive techniques in the discovery and assembly of learning material or content from potentially distributed sources or repositories. The fourth category, adaptive collaboration support, intends to capture adaptive support in learning processes that involve communication between multiple users, and collaboration towards common objectives.

The categories of Adaptive e-Learning Systems, according to Andrews, Barrios, Gütl, Mödritscher, Pivec, Preis & Trummer (2004), are: short-term and long-term, and static and dynamic. The classes of indicators to adapt are: background knowledge, domain-specific knowledge, cognitive abilities, constitutional attributes, preferences and learning targets (Brusilovsky, Schawarz & Weber, 1996). In adaptive systems using eye-tracking to monitor

user behavior, the possible indicators for adaptation could be: disorientation, and reading-scanning. And parameters could be: fixations and saccades – general; and saccadic velocity (tiredness or mental effort) and blinks (tiredness) – specific.

Some of the models that are typically found in ALEs are: the domain model, the learner model, the group models, and the adaptation model. The domain model or application model is usually a representation of the course being offered, considering that most current ALEs are focused on adaptive course delivery. The learner model is usually used to refer to special cases of user models that are tailored for the domain of learning, with variations on the specific approach to modeling. Assembled dynamically in most cases, the group models try to capture the characteristics of groups of users, based on identification of group learners that share common characteristics, behavior etc. The adaptation model incorporates the adaptive theory of an ALE at different levels of abstraction, defining what can be adapted, as well as when and how it is to be adapted.

A proliferation of approaches in representation and utilization of ALEs' models are currently observed. Brusilovsky points towards the need for standardization of the adaptation modeling process and describes efforts in this direction.

Rumetshofer & Wöß (2003) offer an example of an adaptation framework, with an approach that focuses on the methodology of adapting learning material and the learning environment with respect to cognitive differences of students. The system, in this way, has to provide two sets of data: the learning knowledge in the form of learning objects equipped with psychological information and adaptation rules which aims to determine the mapping between a student's characteristics and learning preferences, as well as the impact of the kind of response delivered to this individual.

The promise of Adaptive Learning Systems towards the ideal of individualized learning is enormous. A shift from the traditional emphasis on technical features, though, needs to be made towards their pedagogical use. In addition, differences in learning needs should be acknowledged and accommodated throughout the design process of systems and learning materials. Issues such as the influence of media upon the instructional and learning process, furthermore, need also to be taken care of.

The following section presents the conclusion and suggests future steps.

Conclusion

Research on the efficiency of distance learning presents opposing numbers across studies, varying from less to equally effective as traditional education. Due to weak research designs, though, much of the studies that were conducted from the 1980s to 1990s, rather than being simply confusing, should be considered inconclusive.

Until recently, researchers and developers have more often than not concentrated on technological issues and failed to deal with more important ones - such as different learning needs, the impact of media on instruction and learning, or new roles for teachers, students and system administrators. And despite noticeable attempts to include some learning theory or acknowledge differences in learning styles of students that have been made by several

researchers, these attempts are still scattered and, distant from the ideal of individualized learning.

Nowadays, a large number of distance learning solutions are available in the market, including Virtual Learning management software systems and Adaptive Learning Environments. The first seeks to support student-centered learning through a set of synchronous and asynchronous tools, and the second, to provide an interface capable of automatically tailoring itself initially to the user and of coping with the dynamically changing user requirements that emerge during interaction.

The technological potential alone, as discussed throughout the paper, is useless if the pedagogical use of those systems is ignored. Therefore, the design and development of VLEs and ALEs should be centered on the teaching and learning processes, and on how to support and facilitate them. This is one of the main unsolved problems in the field. Lack of evidence regarding the efficiency of these systems is another.

Comparative studies, with controlled populations of traditional and e-learning students, will help elucidate the effect of adaptive technology on teaching and learning and provide answers regarding how close that brings students to the ideal of individualized education.

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