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An adaptable learning environment that is centred on student learning and knowledge resolution

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ABSTRACT: A framework for an adaptable electronic learning environment is presented in the article. The authors' research has found that while there have been tremendous strides in providing electronic-based course content (e-books, e-solutions, etc), current technologies are lacking in their capability to provide course content that is tailored to an individual's preferred learning style and are unable to direct students through the correct course content when gaps in student knowledge have been identified. The framework developed here incorporates two loops that interact to achieve learning: an instructor-centred loop to develop and revise course content based on learning objectives and gaps in knowledge, and a student-centred loop that utilises learning theory and assessment research to present the course content to students and direct them through course content when misconceptions are identified. The aim of this research is to provide an electronic environment that supports the development of content according to defined learning objectives, delivery of course content in a format tailored to an individual's preferred learning style, assessment of student knowledge to identify misconceptions and the ability to develop and revise course content to close gaps in knowledge.

INTRODUCTION

Over the past several decades, cognitive research has clearly shown that there are strong links between learning, retention and so-called preferred learning styles. That is, students have different preferences in the pace, order and way (format) that knowledge is presented to them.

One classical learning model by Felder and Silverman differentiates four dimensions of learning style (intuitive/ sensing, visual/verbal, active/reflective and sequential/global) in an attempt to explain the way a person understands new information [1]. For example, sensing learners are more practical and look for specific facts, visual learners prefer pictures such as charts and diagrams or visual demonstrations, and verbal learners prefer that information be presented in written or spoken words. Active learners prefer to be actively involved in learning or *learn by doing* (experimenting, problem solving, etc) while reflective learners understand best after having been afforded the time to think or reflect on the material presented. The sequential/global dimension refers to the preferred order in which the information is processed. Global learners would rather have new knowledge represented in the *big picture* (breadth) while sequential learners prefer information to be presented in an organised, step-by-step manner. Thus, the media chosen to present new knowledge (content) and the ability of the delivery mechanism to direct students through the content, highly influences the capabilities students have in processing and learning new knowledge. Research has also shown that a student who is motivated and taught according to their preferred learning style will achieve higher levels of retention and knowledge gains [1-4].

The electronic formatting and delivery of course content can provide a means to tailor content to an individual's learning style, since it is capable of providing the following:

- Navigation systems to support both linear (sequential) and non-linear inquiries of the content (knowledge base).
- Multiple format options of the content (eg both text and graphics).
- Multiple speeds for displaying the content.
- Editing capabilities for correcting, adding and deleting content breadth and depth.

In direct contrast, these capabilities are generally not available for an instructor utilising a traditional delivery system with paper content.

This may explain why the trend in engineering education has been to require more and more computer usage and online technologies in the classroom. In fact, many of the top-ranked engineering colleges in the USA have instituted laptop programmes for their undergraduate curriculum. The general opinion is that laptop computing environments support collaborative group and cooperative approaches to learning, provide faculty with the means to develop innovative teaching methodologies, and improve the efficiency of the delivery system by providing *anytime, anywhere* course access. The goal of these programmes is to provide a new classroom environment of student-centred learning where the faculty (instructor) acts as a *facilitator for learning* rather than a *keeper of knowledge* [5].

Fuelling the movement to utilise computer- or Web-based systems for content delivery are the results from the following researchers:

- O'Riordon and Griffith made the argument that Web-based education systems encouraged more active participation from the learners by providing the means for them to control topic order and pace [6].

- Saddik, Fisher and Steinmetz contended that the use of interactive learning technologies in education supported superior forms of teaching [7].
- Kearsley reported that Web-based (online) learning education improved student attention, as well as their engagement [8].

In addition, the National Science Foundation (NSF) has placed strong emphasis on requiring funded researchers to incorporate their research into the classroom and to attract and retain underrepresented students, particularly in engineering disciplines. Past studies have shown that most female students prefer and take a more active role in creative, cooperative learning activities [9][10]. Furthermore, African-American and Mexican-Americans also performed better in cooperative-learning environments [11][12]. As such, electronic-based delivery systems have been purported as a tool to attract and retain theses types of students [13].

Consequently, engineering schools have seen their traditional, lecture-based delivery system replaced with online or electronically based interactive classrooms, which has placed increasing demands on engineering faculty (instructors) to provide electronic course content and interactive assessment tools (assignments, projects, quizzes and tests). Although the ability of the electronic classroom to actively engage the student has been well documented, research lags in documenting or assessing whether these new environments are more effective than the traditional classroom in terms of increasing the amount of learning students achieve or if the electronic classrooms are more effective in supporting the retention of new knowledge.

Additionally, educational research has shown faculty (instructors) who teach using learning objectives provide their students with learning advantages, regardless of the delivery system chosen. Learning objectives are active statements of what a student is supposed to accomplish (eg at the end of a particular course, a student will be able to perform regression analysis). Establishing clearly defined learning objectives assists an instructor in developing content and assessment tools to identify knowledge gains and misconceptions (concepts learned incorrectly, eg a student is able to calculate the effect but identifies the wrong cause for that effect).

Learning objectives were first documented by Bloom in his handbook, *Taxonomy of Educational Objectives in the Cognitive Domain* [14]. Bloom's taxonomy states that there are hierarchical classifications of learning objectives where a student is expected to complete the lower level learning before moving on to the next learning objective. These learning objectives, from the lowest to the highest level of classification, are as follows:

- Knowledge: a student can recall the information presented.
- Comprehension: a student can restate the idea in different words.
- Application: a student can apply the knowledge appropriately to solve a problem.
- Analysis: a student can break a problem into its components and note the relationships of the components.
- Synthesis: a student can rearrange component ideas into a new whole.
- Evaluation: a student can make decisions based on the whole situation.

Note that most learning, even at the university level, tends to be focused on the three lowest levels of Bloom's taxonomy [15]. Furthermore, while the hierarchical nature of Bloom's is the subject of debate in educational research circles, consensus has been reached on the necessity of teaching and designing course content to support higher levels of learning [16].

Consequently, instructors are left with several tasks when selecting or developing course content (independent of the delivery mechanism chosen) in order to support those educational research findings that improve student knowledge gains and retention, including:

- The instructor must have clearly defined learning objectives for students and selected or developed the course content and assessment tools around those learning objectives.
- The instructor must have the means to identify each student in terms of their preferred learning style.
- The instructor must have the ability to place and format course content and assessment tools into appropriate media in order to support the presentation requirements of the various preferred learning styles of students.

While the use of electronic technologies for content delivery can have clear advantages over traditionally delivered content, research has not been directed at how the physical and cognitive characteristics of learners impact their ability to use technology; thus, current software interfaces do not have the required features to accommodate these differences, even though this concept was first introduced by De Diana and van der Heiden in 1994 [17]. De Diana and van der Heiden argued that electronic study books should be adaptable to personal learning styles and navigation needs so that a learner can have more control over the learning process.

PROPOSED ADAPTABLE LEARNING ENVIRONMENT

Instructors are not typically tasked with, or involved in, developing the electronic media to support content delivery. In general, instructors are tasked with drawing upon, developing and packaging *knowledge* in a form that is delivered as *course content* (lectures, projects, homework, etc).

The issue is to bridge the gaps between the educational researchers who understand the learning process, the authors that provide knowledge sources (e-books, e-solutions manuals, etc) and the instructors who develop and package the course content and assess student knowledge, misconceptions and retention.

An Adaptable Learning Environment is proposed using an expert system to bridge those gaps (see Figure 1). This expert system is the instrument to support individually tailored user interfaces and provides the ability to test students for knowledge gains, retention and misconceptions. Here, the expert system and content, although separate, interact to produce unique interfaces for each individual (including the instructor).

The separation between the expert system and the content allows for the definition of multiple user interfaces to support individual-learning styles, as well as an instructor's interface to control content. Consequently, there are two loops within the Adaptable Learning Environment: one centred on the instructor and another centred on the student.

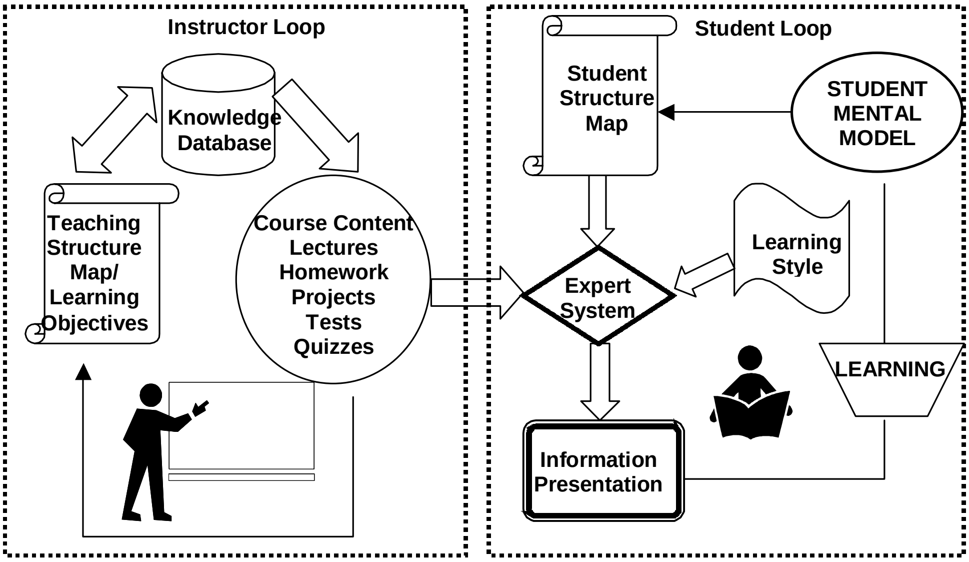

Figure 1: Proposed Adaptable Learning Environment.

The instructor loop allows the instructor to access the knowledge base of possible content (as provided by the author) to customise courseware and topical content for students as based on the course learning objectives. The end result is a teaching structure map of the specific topics and prerequisite knowledge required to support the course's learning objectives and a set of choices made by the instructor to support the delivery of the course and the assessment methodologies (eg lectures, homework, quizzes, etc).

The student loop involves the expert system assessing the incoming knowledge of students (varying degrees of prerequisite knowledge) and their preferred learning style. As learning is achieved, the student *updates* his/her mental model of knowledge. Since mental models cannot be documented, a student structure map is used to assess the amount of knowledge a student has attained at any point within the learning process. Now, both the teaching structure map and the student structure map represent the knowledge or level of understanding of a particular topic and can be represented linguistically, graphically, symbolically, etc. For example, if a concept map paradigm is used, topics are represented as nodes and the relationships between topics are represented as arcs [18].

The goal for the expert system, then, is to evaluate the student structure map against the teaching structure map in order to identify missing or incorrect (misconceptions) student knowledge. The expert system then utilises the missing or incorrect (misconceptions) student knowledge to obtain the appropriate content required to continue the learning process and the student's preferred learning style to optimise the presentation of that information (content) to the student. Consequently, the learning process supported by the expert system within the student loop is iterative and the number of times the process is invoked depends upon the student's ability to master the topic.

The separation of the content from the interface design and the use of an expert system within the Adaptable Learning Environment have some clear advantages compared to other paradigms developed for electronic learning environments. Brusilovsky, Eklund and Schwartz's authoring tool, *InterBook*, provides adaptive presentation and navigation features but lacks the ability to tailor the navigation and presentation system to the preferred learning styles of the students [19]. Likewise, the computer-assisted learning system, *Mentor*, of Koronois focuses on automating the design and development of multimedia courses and lacks assessment and interface adaptability capabilities [20]. While Gardner, Sheridan and White provide an architectural structure to support the delivery of content, the ability to assess learning electronically and perform administrative functions within a Web-based environment, they too fail to address supporting individual learning styles [21]. Beaumont presents an interactive tutoring system, *Anatom-Tutor*, for anatomy content [22]; Brusilovsky, Persin and Zyryonov provide an intelligent tutoring system for learning programming and physical geography [23]; yet both of these systems also fail to adapt and present the content based on the needs of students' individual learning styles.

PROGRESS AND RESEARCH ISSUES

The framework for the Adaptable Learning Environment is currently under development at the School of Industrial Engineering, University of Oklahoma, Norman, USA. Current research efforts are directed at understanding how learning occurs in an electronic environment. While a vast amount of research is known about learning in a traditional classroom, a void exists in the area of understanding learning in a technology-driven environment.

The first phase of the research has been aimed at developing a comprehensive taxonomy of learning models and their characteristics for developing a similar taxonomy for electronic learning. Experiments have been conducted to document learning within an electronic learning environment and a traditional learning environment, where students are evaluated prior to the experiment against a set of known (traditional) learning style models. Characteristics of traditional learning style models are used to identify those that transfer directly to an electronic learning environment and those that need to be adapted [24].

In addition, research is now being conducted on the appropriate paradigm to capture the student structure maps. At issue is the ability to identify a tool or technique that can effectively quantify a student's structure map. This tool will be used as input for the expert system to modify the presentation of information and must be consistent with the mental representation already held by the learner [25].

Statistics content has been authored for a prototype knowledge database. The comprehensive nature of statistical topics to be included in the knowledge database has been identified and assessed using a modified Delphi technique. A survey was developed and distributed to engineering faculty who are considered to be possible statistics instructors (who would use the course content in follow-on courses or had previously taught a statistics-based course). From the survey, a list of statistics topics to be included in the database have been identified, linkages between topics have been established and pairings between topics and learning objectives have driven knowledge database development for statistics topics. An electronic textbook for an upper-level engineering statistics course is currently being compiled based on the statistics database.

Functional specifications for the expert system are also being established. Contingent on the results from the electronic learning theory and the structure map research efforts, the functional specifications for this expert system are scheduled to be finalised by fall 2003.

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