AN ADAPTIVE WEB BASED LEARNING ENVIRONMENT

George Angelakis, BA Comp. Sci.

A dissertation submitted to the University of Dublin,

in partial fulfilment of the requirements for the degree of

Master of Science in Computer Science.

September 2000

Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

Signed: _____

George Angelakis

September 2000

Permission to lend and/or copy

I agree that Trinity College Library may lend or copy this dissertation upon request.

Signed: _____

George Angelakis

September 2000

Acknowledgements

I would like to thank my supervisor Brendan Tangney for all the assistance I received during this course and especially for the completion of this thesis. Thanks also to Bryn Holmes, Vinny Wade and all my classmates, for their help and support throughout the year.

Summary

In recent years enormous progress has been made in World Wide Web technologies. This is making the Web an even more promising way to deliver educational material. New technology, integrated with experiential education, can increase the effectiveness and efficiency of the learning process. Java Servlets, XML, XSL, CSS and Java applets make dynamic creation of web pages, easier and richer. User profiles are widely used in learning environments contributing new approaches in the way computers are used to deliver education. Profiles can be built with information requested directly from the learners or from analysis of the way learners interact with the learning environment.

This thesis focuses upon the creation of a flexible and rich environment, which can be used to improve the quality and power of web-based learning. It presents a distributed approach to the design and implementation of an improved learning environment. Both instructional and assessment material will be generated dynamically for each user upon request. The system will be adaptive to users' profiles, so that users with different profiles may be presented with different content. Users will have control over their profiles. Additionally, it will be possible for the system to automatically update a profile. The pages containing the material will be made up of modules. Modules can be html, text, applets or multimedia files.

A prototype system will be created for the instruction of Mathematics for secondary education. The system will be available over the World Wide Web. A Microsoft Access DBMS will be used for the storage of students' profiles, instructional and assessment materials. Java Servlets and JDBC will be used for the connection to the database and the creation of all the Web pages.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ASP	Microsoft's Active Server Pages
AVI	Audio Video Interleaved
AWS	Apache Web Server
CBT	Computer Based Training
DHTML	Dynamic Hypertext Mark-up Language
GIF	Graphics Interchange Format
AHA	Adaptive Hypermedia Architecture
GUI	Graphical User Interface
HTML	Hypertext Mark-up Language
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	Instructional Management System
JPEG	Joint Picture Expert Group
JDBC	Java Data Base Connectivity
MathML	Mathematical Markup Language
MOV	Quick Time Movies
MPEG	Motion Picture Expert Group
ODBC	Open Data Base Connectivity
OLE	Object Linking and Embedding
PDF	Portable Document Format
PPT	PowerPoint file format
RDBMS	Relational Data Base Management
RM	Real Systems Media format
SDK	Software Development Kit
SGML	Standard Generalised Mark-up Language

SQL	Structured Query Language
SWF	ShockWave Flash file format
TCP	Transport Control Protocol
TCP/IP	Transport Control Protocol
UDP	User Datagram Protocol
URL	Universal Resource Locator
WAV	Wave file format
WMF	Windows MetaFile
XML	Extensible Mark-up Language
W3C	World Wide Web Consortium

1. INTRODUCTION

1.1. INTRODUCTION

In recent years enormous progress has been made in World Wide Web technologies. This is making the Web an even more promising way to deliver educational material. Many courses have been developed for providing distance education, where physical contact between the students and the educator is not necessary. The World Wide Web is also used as part of a traditional course providing both main or supplementary course material online.

The research in the area, though, is continuous. Technology, integrated with pedagogy and experiential education, can increase the effectiveness and efficiency of the learning process. Web pages can be generated on the fly, quicker and with richer content as technologies like e.g. Java Servlets, XML, XSL, CSS, Java applets and multimedia capabilities become more sophisticated. User profiles are contributing new approaches in the way computers are used to deliver education. Profiles can be built with information requested directly from the learners or from analysis of the way the learners interact with the learning environment. So it is possible to build learning environments that not only make learning more interactive but also adapted to the individual learner.

1.2. MOTIVATION

There is a growing interest in educational institutions in developing learning environments for online delivery of education. Material is

published on the Internet, aiming to help distance education, or, as a supplement to courses in face-to-face classes. Although the effectiveness of the World-Wide Web as a medium for delivering education has been questioned, the current practice and research seems to prove it otherwise.

In a Web-based learning environment three dimensions should be considered: the social dimension, the technological dimension and the educational dimension. The majority of Web-based learning environments that exist focus more on the technological dimension and less on the educational or the social dimension. Research in the field of artificial intelligence in education can provide us with ideas for more personalized learning environments. User profiles are increasingly used in learning environments.

Assessment is an important part of an online learning environment as it is for any learning process. In addition to evaluating the students' progress, assessment helps students learn. A student's results in assessment tests can be recorded in the student's profile, making it possible for the system to adapt to the way each student learns. Also additional information can be provided to help students clarify their weak points.

Overall, online environments should be more than ways of delivering text. The content must be dynamic allowing for interaction according to the constructivist approach. The practice, however, shows that most of the existing online learning environments lack in quality and use of all the features of modern technology.

1.3. OBJECTIVES

The objectives of this thesis are:

- The design of a dynamic and adaptive learning environment over the WWW that offers:
    - Adaptive delivery of the educational material to the students; and
    - An assessment system that gives feedback to the system.
- The implementation of a prototype system that according to the design will be adaptive to the users' profiles. Example course material for the teaching of mathematics (trigonometry) in secondary education will be used. The prototype system will support dynamic creation of:
    - web pages containing the instructional material, according to the user's profile; and
    - auto corrected tests for the assessment of the users.
- The implementation of the interface for the management of the course structure and the course material over the World Wide Web. The interface must make it easy for non-computer experts to populate the course material database.

1.4. APPROACH

In this dissertation previous work in the area will be considered. The prototype will be implemented and tested, mostly from a technological point of view. The pedagogical issues will be taken into consideration but will be tested and evaluated thoroughly from educators taking the MSc. course "IT in Education", in Trinity College. Therefore the prototype must be robust and fully functioning enabling the instructors to use it without requiring detailed knowledge of the computer technology issues (e.g. databases).

The environment will be adaptive to the users' profiles. Two details will be mainly used to construct a student's profile; the preferred learning style and the difficulty level. The learning style of an individual will not be assessed by the prototype. To assess their preferences in learning, the students can use available assessment questionnaires on the Web or any other source. The student himself will decide the level of difficulty best suited for the existing knowledge on the subject. A simple introductory test will be available as well as the option to change the difficulty level during the course, according to test results. This approach lends itself to the constructivists' approach that the learner must participate actively in the learning process.

The system will be available over the World Wide Web. Databases will be used for the storage of students' profiles and of all the material, instructional and assessment. The system will be dynamic. Pages will be generated on the fly with the use of Java Servlets and JavaScript when necessary. The pages containing the material will be made up of modules. Modules can be html, text, applets or multimedia files. The text or html content of a module can be inserted directly into the database, or stored in a file with a reference to it in the database. All other files will be uploaded to the server and referenced in the database.

1.5. DOCUMENT STRUCTURE

This chapter was an introduction to the dissertation presenting the objectives and the approach taken. Below is a brief description of the structure of this report and of the following chapters.

- **Chapter 2. INTRODUCTION**

  This chapter will present a review of the underlying theory that

was used to support this thesis.

- **Chapter 3. EDUCATION ON THE WORLD WIDE WEB**

  This chapter will describe and evaluate learning environments and material available on the Web.

- **Chapter 4. DESIGN**

  This chapter will outline the requirements and the design of the proposed adaptive learning environment.

- **Chapter 5. IMPLEMENTATION**

  This chapter will present the implementation of the prototype built for this dissertation.

- **Chapter 6. EVALUATION**

  A critique of the prototype system built from a technological point of view will be presented in this chapter.

- **Chapter** Error! Reference source not found.**. CONCLUSIONS**

  A summary of the thesis with proposed future work.

2. BACKGROUND

2.1. INTRODUCTION

There is a growing interest in educational institutions in developing learning environments for online delivery of education. Material is published on the Internet, aiming to help distance education, or, as a supplement to courses in face-to-face classes. Although many researchers question its effectiveness, the World-Wide Web seems to be a promising medium for delivering education online. However, there is no standard that describes how the course material should be delivered over the network.

Current practice of developing online courses falls into one of two categories: custom initiatives developed by the institutions themselves, or customisable applications from the software industry.

Trying to identify the components of a Web-based learning environment three dimensions should be considered: the social dimension, the technological dimension and the educational dimension. The majority of Web-based learning environments that exist focus more on the technological dimension and less on the educational or the social dimension.

Online environments should be more than ways of delivering text. The content must be dynamic allowing for interaction according to the constructivist approach. Constructivists suggest that information is processed in a personal way and the learner constructs knowledge instead of just accumulating information.

The Learning Styles theory provides ways to make an online environment adaptive to the way students learn best.

2.2. PEDAGOGY

Over the years, there has been a shift in pedagogical perspectives from a "transmission" model (the idea that learning is essentially the assimilation of information) to the adoption of a more "constructivist" framework (the idea that learning is an active process of constructing meaning on the part of each individual learner).

In his thesis “Courseware on the fly”, Dillon [1] reviews the learning theories: Behaviourism, Cognitivism and Constructivism. His thesis includes aspects from all three theories but mainly constructivism. Constructivism, which was influenced largely by science teaching, asserts that knowledge is constructed by the learner, not passively received or assimilated. To the constructivists view, learning is an adaptive progress and can be described as a change constructed from experience.

Online learning development should focus on supporting the active participation of the student in constructing personally meaningful representations of the material. It must not be just presentation of information, but the student must think about the material presented. The student must analyse the information presented and discuss it with other students.

2.3. LEARNING STYLES

2.3.1 Concepts

Learning style has been defined in many different, yet similar ways. Keefe [2] defined learning style as a number of factors (cognitive,

affective, psychological) that serve as indicators of how a learner perceives, interacts with and responds to the learning environment. James and Gardner [3] defined learning style as the way in which learners best perceive, process, store and recall what they are attempting to learn.

Learning style models vary in many ways. McLoughlin [4] discusses two different traditions in learning styles research. One approach derives from psychology (cognitive-perceptual) and focuses on different modes of processing and presenting information. Riding and Cheema [5] identify the *holistic-analytic* and *verbaliser*-imager learning styles. The second approach (learning-centred tradition) focuses on approaches to learning, and conceptions of learning. Different learning style that have been identified here are activists, reflectors, theorists and pragmatists.

Although it is possible to identify the learning styles of individuals, Robotham [6] questions whether such an approach is valid. He is concerned that using existing inventories of learning styles, individuals are allocated to a narrow range of categories, containing a limited number of learning activities to which they are, in theory, best suited. He suggests that learners should be self-directed and that they must have the choice to use a particular learning style or not. Felder [7] is also discussing the benefits from teaching students with all learning styles. He refers to it as "teaching around the cycle".

2.3.2 Benefits

However the benefits from using learning styles in the learning process are not questioned by most of researchers. Multimedia and computer software can be used to address the needs of a variety of learners. Montgomery [8] claims that the use of multimedia engages students actively in their

learning and exposes students to the subject matter in exciting ways that traditional learning methods cannot.

Another benefit from attending to learning styles is that we place more responsibility on the students themselves. Not everybody is equally productive at the same time of the day and some may require more breaks.

2.3.3 The Sensory Intake of Information Approach

In this thesis an approach based on our sensory intake of information will be adopted. Gentry [9] categorise learning styles as: physical, sensory preferences into visual, auditory, tactile and kinaesthetic. Along these lines, a learning style survey developed at Diablo Valley College [10] provides an online questionnaire identifying the following learning styles.

The Visual/Verbal Learning Style

Learners of this type learn best when information is presented visually and in a written format. They benefit from having lists with the essential points and outlines during lecture and by taking notes. They tend to study in a quiet room.

The Visual/ Nonverbal Learning Style

Learners of this style learn best when information is presented visually, in a picture or design format. They benefit from instructors who use visual aids such as film, video, maps and charts. They benefit from information obtained from the pictures and diagrams in textbooks.

The Tactile/ Kinaesthetic Learning Style

Learners of this style learn best when physically engaged in a "hands on" activity. They benefit from a lab setting where they can manipulate

materials to learn new information and when being physically active.

The Auditory / Verbal Learning Style

Learners of this type learn best when information is presented auditory in an oral language format. In a classroom setting, they benefit from listening to lectures and participating in discussions. They also benefit from obtaining information from audio.

2.4. ASSESSMENT

Assessment is an important part of an online learning environment as it is for any learning process. It demonstrates to the instructor, but also to the students themselves, the progress students are making. In addition to evaluating their progress, assessment helps students learn. Some of the advantages of an online assessment system are that it saves time for tutors while the feedback to the students is quicker. In addition, a student's profile can be built through assessment making it possible for the system to adapt to the way each student learns and focus on each student's weakest points.

O'Reilly and Patterson [11] discuss the importance of assessment to the learning process and the use of the WWW to enhance assessment in learning contexts. Incorporating the interactive nature of WWW for the purpose of assessment can cost little but add value in possibilities for collaborative, resource-based learning.

Thelwall [12] survey some of the reasons for using computers for assessment. The results showed that random-based tests could have a number of advantages over fixed assessments. Assessment has to be viewed within the learning environment in which it is situated and it can have an impact upon a student's study strategy, e.g. increased

revision, making computer-based assessment a versatile educational tool.

Ogata *et al.* in their paper [13] describe a system for supporting the exchange of marked-up documents by e-mail. For the representation of the documents Communicative Mark-up Language (CCML), which is based on SGML, was used. The results showed that with the exchange of marked-up documents it was easy for students to understand the teacher's corrections because of the feedback they were getting.

2.5. LEARNING AND THE WORLD WIDE WEB

The reports of many researchers and the continuing research on the subject indicate that the World Wide Web is an effective medium for delivering education.

Barger & Barger [14] see possibilities for interaction through the Web despite different opinions that the Web does not truly promote learning as the network connection speeds and the hardware limitations do not give the amount of interaction learning demands.

However, the Internet is becoming more reliable and evolves into a communications medium allowing for rich interaction. The World Wide Web not only delivers text but also supports the use of multimedia elements and communication options [15].

The advantages of the use of Web-based courseware, as a supplement to the traditional delivery of a course in the classroom, are discussed from Papaspyrou *et al.* [16]. The students can study the material at their own pace, any time, from any place and the teacher acts as facilitator assisting the learning process. The system developed is a distributed system using a client-server model. The subsystems that consist the system is a) the

administrative and management subsystem b) the presentation subsystem and c) the communication subsystem.

Makrakis *et al.* [17] claimed that an effective open and distance learning (ODL) hypermedia system can be produced provided that the courseware is well designed and with dynamic interfaces. The effectiveness of a Web-based ODL system developed and trial used at the National Technical University of Athens (NTUA), Greece, was evaluated. This evaluation research suggests that such a system design should be centred on the characteristics of the students, the courseware and the nature of the learning task rather than on the underlying technological platform. A number of suggestions were made for achieving this, such as: including more interactive examples, assignments, animation, and exercises, enriching the content with new material which should be presented in a more analytical way, providing summaries at the end of each chapter, highlighting the major aspects and key concepts, and providing better consistency of the topics, especially by merging small units.

The practice, however, shows that most of the existing online learning environments lack in quality and use of all the features of modern technology. Mioduser *et al*. [18] present a study of the characteristics of Websites as teaching and learning environments. They claim that most sites, with only some exceptions, offer plain information, with lack of interactivity and without taking advantage of the new technological resources (e.g. forms, Java applets, Shockwave).

On some other occasion, University of Washington fundamentally rethought its approach to the support of technology in teaching and learning ([19]). They re-examined its programs, practices and facilities, engaged stakeholders in broad conversations on the role of technology in teaching, and embarked on a significant redesign of its support

model and physical spaces. The study found that courseware was mostly tool-focused than people-focused and expressed the belief that for technology to be effective its use must be driven first and foremost by pedagogical goals.

2.6. LIMITATIONS

The initial efforts toward using the Web for teaching was done by some early adopters [20] noted that an examination of the structures and assumptions that underlie decisions about pedagogy and implementations are the more reliable keys to establishing sound instruction via distributed learning environments. The lack of consideration for pedagogical issues has hindered utilization of the learning environments for educational purposes.

Quentin-Baxter's study [21] has investigated the use of interactive hypermedia learning environments. In this study, part of a larger PhD study, audit trails and questionnaires were used to reveal that students overestimated the amount of material they accessed from the total amount available. The interactive strategy adopted by learners affected the amount of information accessed, questioning the increasing use of interactive hypermedia in teaching without further research. The findings of this study appeared to contradict with the concept that learners know what's best for them.

Hara & Kling [22] report that students' frustration was a big problem in distance education. Online learning has potential for providing rich environments for students, but also trade-offs. They state that the emphasis is given to technology and not pedagogy. Research is needed, designed to teach instructors how the use of technology and pedagogy could make online learning beneficial for students.

Stelzer & Vogelzans [23] tried to give recommendations for the student isolation problem in online learning and how to keep students motivated. Technology can help not only with communication tools (email, videoconference, chat) but also with the idea of shared space and online activities.

2.7. DESIGNING ONLINE LEARNING ENVIRONMENTS

Wild & Omari [24] outline certain pedagogical characteristics of an online learning environment and some of the limitation of the Web that online course designers must have in mind. The features demanded for a constructivist approach are:

- Dialogue, between learner and materials (information).
- Dialogue, between learner and content author (instructor).
- Dialogue, between learners to take action on information.
- Dialogue, between learners to negotiate task goals.
- Dialogue, between learners to reflect and interact with descriptions of the world.
- Dialogue, between extending or adapting the materials (information).
- Dialogue, between providing feedback, especially intrinsic feedback, on learners' actions.

Oren *et al.* [25] propose a particular educational configuration based on the combination of three components: a virtual community (social dimension) hosted by an appropriate virtual environment (technological dimension) and embodying advanced pedagogical ideas (educational dimension). Sense of belonging, extend of presence and status definition are attributes that contribute to the function of a community. Technology-based attributes crucial to the evolvement of a virtual community are: the

sense of being there, multi-user options (e.g. MUD), variety of communicational means and meta-level design.

In an initiative labelled "Catalyst", Donovan & Macklin [19] used the Web as the primary means to deliver support. The final design of the Catalyst Web site includes five core components:

- Method Guides, focusing on instructional practices and implementations of technology that can enable these practices;
- Profiles of campus educators, describing in their own words the ups and downs of their experiences using technology;
- Quick Guides, providing standardized, task-oriented guides to the implementation of a particular technology;
- Technical Documents, providing step-by-step how-to instruction on a wide range of topics;
- UWired Tools, allowing educators to generate custom scripts from Web-based forms, providing them with advanced functionality without any programming.

2.8. ADAPTIVE HYPERMEDIA

2.8.1 Adaptive Hypermedia Systems

A lot of research is done currently on the area of web-based education and of adaptive hypermedia systems (AHS). AHS make possible the delivery of personalized material to the users of the system. Different techniques have been developed to adapt a system to a user's profile. Brusilovsky [26] reviews the research on adaptive Web-based educational systems and

discusses the adaptation technologies:

- Curriculum sequencing technology provides the student with the "optimal path" through the learning material.
- Intelligent analysis of student solutions deals with students' final answers to educational problems, supplying feedback not only if the answer is wrong but also what exactly is wrong, what is missing and give extensive feedback to the student.
- Interactive problem solving support provides the student with help on each step of problem solving (giving hints or executing the next step). The Java technology provides a nice interactive interface for the implementation of such systems.
- Example-based problem solving support helps students solve new problems using, as help, examples from their earlier experience.
- The adaptive presentation technology adapts the content of a hypermedia page to the user's goals, knowledge, and other information stored in the user model. In such a system pages are not static but adaptively generated.

Adaptation technologies can improve the quality of the web-based education and although these technologies are mostly in a research level, some of them are being implemented.

Working in the same area, De Bra [27] distinguishes between adaptable and adaptive hypermedia. In adaptable hypermedia the user provides a profile and the application corresponds to the selected profile. In adaptive hypermedia the system monitors the user's behaviour and adapts the presentation accordingly. Finally, he believes that the nature of the Web allows great advantages for adaptation technologies but also

caution that there are some problems with authoring such systems. In most of the adaptive systems developed the people who develop the applications who are usually computer science people, do the authoring as well. But it is quite complicated for people with not enough computer background.

Evaluating an AHS is a difficult task as well. De Bra and Brusilovsky [28] describe it as "a combination of the adaptive methods and techniques that are used and of the way in which the adaptation is used". They review some evaluations of AHS finding improvements in student performance.

2.8.2 User Profiling

The Learning Technology Standardization Committee of the IEEE offers standards both for the description of Learning Object Metadata and Personal and Performance Information (PAPI).

PAPI [29] tries to standardise the way the student records are represented and how this information is sent to other applications. The standard distinguishes between the personal and the performance information and proposes that they must be kept separately for privacy reasons. This specification describes in general the structure a student record must have.

The IEEE P1484.12/D4.0 standard specifies the syntax and semantics of learning object metadata (LOM). LOM can be defined as the attributes required to fully and adequately describe a learning object. The LOM standard focuses on the minimal set of properties needed to allow learning objects to be managed, located, and evaluated.

2.9. SUMMARY

The theoretical background for this dissertation was discussed in this chapter. Some approaches in the literature, to the design of an online

learning environment were presented. The theory of learning styles and adaptive hypermedia systems were discussed. Assessment was recognized as an important part in the learning process. The next chapter will present the state of the art in the World Wide Web and learning.

3. EDUCATION ON THE WORLD WIDE WEB

3.1. INTRODUCTION

Some institutions have taken the approach to design and build their own World-Wide Web pages while others prefer the software packages for developing Web courses that the software industry offers. Software packages require the use of expensive servers and the support of an information-services department, while others are designed to let professors create online course materials with little or no support. Some of the programs have features such as online conversations and timed online quizzes, but others offer much simpler tasks, providing only course materials and lecture notes.

Several studies (e.g. [30], [31]) have been conducted trying to evaluate and compare the applications commercially available. A brief evaluation of some of the most important features is presented in Table 1.

Features	VCR	Scoop	TopClass	WebCT	D.T	Dillon
Communication Tools						
Internal e-mail	✓	✓	✓	✓	✓	✓
Threaded Discussion Board	✓	✓	✓	✓		
Chat facility		✓	✓	✓		
Whiteboard			✓	✓		
Newsgroup			✓	✓		
Staff room	✓					
Video Conference					✓	✓
Instructor Tools						
Course planning-managing			✓	✓	✓	
Online testing			✓	✓		
Online grading			✓	✓		
Customize student curriculum			✓	✓		
Student tracking			✓	✓	✓	
Assign course material		✓	✓	✓		
Self-test tutorial questions			✓	✓		
Student Tools						
Authentication	✓	✓	✓	✓	✓	✓
Bookmark management			✓	✓		
Multimedia support		✓	✓	✓	✓	✓
File submissions			✓	✓		
Progress tracking			✓	✓		
Access to grades			✓	✓		
Automated glossary			✓	✓		
Automated index tool			✓	✓		
Online help			✓	✓		
Search tool			✓	✓		
Student home page		✓	✓	✓		
Management Tools						
Student profile	✓	✓	✓	✓	✓	✓
Online Help	✓	✓	✓	✓		
List of students			✓	✓	✓	✓
Student's performance			✓	✓		
Logout	✓	✓	✓	✓	✓	✓
Adaptive to user profiles						✓

Figure 3.1 Evaluation of learning Environments

3.2. WEB-BASED LEARNING ENVIRONMENTS

3.2.1 Virtual Study Centre

The Virtual Study Centre (VSC) is a learning environment that has been implemented by the Telematics Centre at the University of Exeter, School of Education. The Virtual Study Centre is used to offer online MEd/BPhil modules to teachers. The instructor delivers the material by publishing it as an HTML page or by giving references to articles or books that have to be read. The material published is enriched with audio and video. Students deliver their work that is usually an essay by emailing to the instructor.

VSC uses Ceilidh to implement discussion groups. Ceilidh is a discussion software product from Lilikoi Software, and is used for providing threaded bulletin boards with file attachment and e-mail. Instructors can post messages to the 'notice board'. All users view these messages. There is a separate discussion that only the instructors can participate.

Other tools used in the VSC include the calendar, with the schedule for all courses, links to relevant web sites and a library with references and online journal articles.

3.2.2 Scoop

Scoop is part of Oracle's Millennium Project Think.com, and provides primary and secondary education schools (teachers and students) with a tool to build collaborative learning communities. System users can create, communicate and collaborate in a closed, and protected educational environment, as well as explore the Internet and create their own communities of common interest.

Each child gets a unique ID and can access emails from any Internet connected computer as part of one or more communities. A search tool is provided (Herald, the Scoop hound) to find articles, discussions and news. Users can set up online discussion groups, brainstorms and debates. The system offers a way for a teacher or expert to mediate and guide the discussion. Teachers will be able to mark children's work online and post an encouraging note with comments. Links to relevant Internet sites can be added to the child's page.

Emails can only be received from people as a reply to an email from another user, unless the user has added the sender to their personal address book. It also allows for mail filtering by blocking email from unauthorised persons outside the environment. You can visit a community, but you can only join a community if invited to do so. Each community has a manager who has some control over what is published and who is allowed to join the community.

Scoop uses Oracle 8i as the Internet platform integrating and centralising the information. The system can recognise text, images, video and audio.

3.2.3 TopClass

TopClass was designed and developed at the University College Dublin, Ireland and is distributed by WBT Systems. It manages the delivery and support of training and education using the Web, and is available on all major platforms. TopClass contains tools for course creation, course management, student management, interactive quizzes and assignments, and communications.

The Discussion List is an area in which discussion can take place between all members of a class by posting messages to the list. WBT Systems

staff will also monitor the discussion list. TopClass has its own built-in e-mail system (this system is totally separate from the personal email). Users can send mail to other people in their class, using the user's TopClass username. “Class Announcements” option is quite similar to the Discussion List, but here, only the system administrators and instructors can make postings. The Class Announcements page is usually used for posting Reading Lists and other information of general use to people taking courses.

TopClass course designers can provide on-demand audio and video using RealNetworks' RealAudio and RealVideo technologies. Also using an html authoring tool the course author can change the look and feel of the web pages and include java Applets. Powerpoint presentations can be added as well.

Auto corrected tests and human corrected tests are used in TopClass. It can perform actions based on the scores received in auto corrected tests. More work course material can be added or a note be sent to an instructor, based on the results received.

3.2.4 WebCT

WebCT is a tool developed in the Department of Computer Science at the University of British Columbia. It facilitates the creation of World Wide Web-based educational environments and can be used for the creation of entire online courses or to publish materials for existing courses.

It allows the course designer to determine the appearance of the course pages (layout, colours, text, counters, etc).

Provides a set of educational tools that include communication tools

(conferencing system, chat and e-mail), student evaluation and self-evaluation tools (online, automatically marked quizzes, and content-related multiple choice questions), a searchable image archive, a linkable glossary database, student collaboration and presentation areas, student content annotation, student homepage generation, course navigation, indexing and searching tools, account administration tools and more.

Administrative tools assist in the delivery of a course. These include student progress tracking, course access tracking, a categorized question database and online quiz creation tool (with historical statistics on performance and automatic marking), a questionnaire delivery and report tool, student access control, grade maintenance and reporting tool, and more.

3.2.5 David Thornton's Learning Environment

David Thornton designed a unified system for the development, delivery and administration of courses over the Internet. The work was part of his dissertation for the degree of Master of Science in Computer Science, to Trinity College, Dublin.

The creation of the course material is done using an html editor. The course structure is stored in a relational database (Microsoft Access) providing reusability and extensibility. Multimedia content supports images (gif, bmp, jpg), audio (wav, ra, mpeg), video (avi, mov, mpeg, rm, asf) and animation files (swf, fla, avi, mov). Multimedia content is embedded to a web page using off-the-shelf tools.

Course delivery is done using HTML. A web browser that supports frames and ActiveX controls must be used (preferably Microsoft Internet Explorer 5.0). Collaborative activities are supported using CuSeeMe for group

discussions and NetMeeting for data conferencing.

HTML pages are generated on the fly, taking the course content from the relational database. It uses Live Software's JRun a java server extension that supports Java Servlets. Compatible servers that can be used include Apache, IIS and Netscape Enterprise Server.

3.2.6 Courseware on the fly

Dillon [1] in his dissertation used an oracle database to store the course structure and the course content. The users are answering a questionnaire about what they want from the course and what is their knowledge on the subject. The application then will generate the course structure that suites best to the user's desires. Meta-information was used to describe the educational objects so that the application would be able to construct a meaningful.

3.2.7 Discussion

Virtual Study Centre was implemented from the University of Exeter and is not a commercial product. It is not as complete as the popular TopClass and WebCT.

Scoop has a pleasant look, is funny to play with but I think that online help is not sufficient (a page describing how the members can use it is missing and would be useful). Scoop is not intended to be a learning environment but a collaborative environment where young students can interact and form communities.

TopClass seems quite easy to use with easy navigation among the course content. It wasn't tested on a real situation but it seemed reasonably fast. Online help seems sufficient. Further exploring on the delivery of

the content needs to be done. Questionnaires can be used and the corrections can be automated or by teachers. Good communication tools are provided.

Studies [32] have shown that the general reactions of students to TopClass were positive. The majority of the students responded that TopClass was easy to use and that they liked the idea of using TopClass as part of a course. Students liked the corrective feedback and supplementary information after the tests showing that assessment in online learning environments help students to check their understandings.

Keith Wright [33] in a report for the University of North Carolina had similar remarks for TopClass only to add some frustration with using TopClass, mainly because of hardware and network problems

WebCT is a very successful product with a large user base and a strong tool for delivering courses online but it is not so easy to administer and requires training and support.

David Thornton's design [34] discussed how distributed technologies could be used for the implementation of an online learning environment and the delivery of courses via the World Wide Web. The use of technologies and tools available at low costs or free of charge reduced the costs involved. The use of a relational database (RDBMS) improves extendibility, scalability and flexibility contrary to proprietary data structures.

Brian Dillon [1] proved that the generation of a course on the fly is possible. The course structure is different based on the student's profile. The profile is created after the user answers a questionnaire. The system is adaptive but the adaptation is limited. There is no change in the user profile after the course has started. This thesis will draw upon this design and will

address some different aspects of adaptive systems.

3.3. TEACHING MATHEMATICS ON THE WEB

This thesis will use mathematics as example courseware. An overview of how mathematics is currently presented on the web, either as courseware or as supplementary material. The course will focus mostly in the teaching of Trigonometry. Mathematics was chosen because it is believed that the teaching on the web can offer valuable help to the students.

An example tool, TechTools [35] is a professional development promoting constructivist pedagogy with modern technologies. Its use showed that the introduction of technology tools into the science and mathematics classroom is difficult, time consuming and not as successful as desired. But it has some good side effects. Evaluation of the tool showed that although males have more experience than females in use of hypermedia and the Internet, and are getting more help by their administrators, females have a stronger belief that technology will promote learning and increase equity for females in the marketplace.

The presentation of mathematical expressions in Web pages and therefore their use in learning environments is problematic. Although HTML has a large repertoire of tags, it does not have tags to mark up mathematical expressions. The only way was to inset images. W3C designed MathML a mark-up language for editing and processing math on computers [36]. The most recent version is MathML 2. MathML consists of a number of XML tags that can be used to mark up an equation (presentation and semantics).

Alternatively, EzMath [37] is an editor that provides an easy to learn notation for embedding mathematical expressions in Web pages. It covers a

subset of mathematics and it creates the mark-up for pasting into Web pages.

3.3.1 Web sites for Trigonometry

Below, there is a collection of sites related to mathematics especially Trigonometry. The URLs are provided at the *LINKS* page of the prototype.

1. maths online

   Maths online is a project based at the University of Vienna, Austria, and is running since March 1998. Its goal is the construction of a modern mathematics-learning site on the web. Maths online tries to realize modern didactic concepts by interactive multimedia techniques. The goal is to contribute to the development of adequate standards for up to date maths education in school, high school, college, university, and adults' qualification. It is a very good site with good quality applets, nicely divided into units. It can be used as supplemental material. There could be more variety in tests. User interface is average. Applets can be publicly used and were used for the example courseware presented in this thesis.

2. A short course in Trigonometry

   A web site maintained by David Joyce, an Associate Professor of Mathematics and Computer Science at the Clark University, Worcester, MA, USA. It's more of an introduction and guide to Trigonometry than a full course. Text material for an introductory course in Trigonometry, applets and a few exercises are what this site offers. The material is simple and the site is easy to use. There is not enough interaction and no self corrected tests.

3. ACTS Networks

   ACTS Networks is an effort funded by the Government of Ireland. It wishes to help teachers, students and parents, with new technologies in education. There are two interesting projects related to maths and other sciences:

   - NAME Project - National Archive for Mathematics Education. A site created for Irish students. Contains mostly text and drawings on high school Trigonometry.

   - Topstudy, a project built by the company Zenith Solutions Ltd. Well presented theorems with the use of Macromedia's Flash (Requires Flash 4).

4. Math Cove

   A site maintained by the associate professor C. P. Mawata and hosted by the University of Tennessee at Chattanooga. Offers useful applets for public use. Can be mainly used for High School Geometry. Contains both applets and text in the form of units. The text is not detailed theory but mostly supplementary.

5. SMARD

   SMARD is the Secondary Mathematics Assessment and Resource Database. SMARD provides an opportunity for secondary maths teachers to share assessment and resources. Most of the assessment and resources available from this site have been classroom-tested, and much of it is non-traditional. Users can add their own material to it. Contains some good links but on the whole, not very interesting.

6. Eric Weisstein's World of Mathematics (MathWorld)

   Eric W. Weisstein assembled this encyclopaedia and is intended

for students, educators, and researchers. Wolfram Research, Inc., hosts MathWorld makers of Mathematica. A complete site with resources for mathematics and a very good link that can be used as supplementary material for reference.

7. Mac Tutor History of Mathematics
   School of Mathematics and Statistics, University of St Andrews Scotland created a collection of over 1000 biographies and historical articles of a mathematical nature. Good for History of Mathematics and biographies of mathematicians. Contains a few applets for the famous curves. Good for reference.

8. Gamelan and Developer.com
   Identical sites by EarthWeb, a New York City enterprise specialized to the development of information technology offering a free collection of mathematics and other applets.

3.3.2 CONCLUDING REMARKS

From the web sites reviewed in this chapter, none gave the impression of a fully functioning environment. The teaching of mathematics related material is not done in a structured way and is more of a repository of either applets or images and text. None of the applications, commercial are not were adaptive or used any adaptation techniques. The next chapter will try to design the environment using material from the sites reviewed, structuring it in a way that best suites the project objectives.

4. DESIGN

4.1. INTRODUCTION

The design of the system will be discussed in this chapter. The proposed learning environment for this dissertation will be designed along the lines of the theory discussed in chapter two of this report. The requirements for an adaptive learning environment will be outlined. The issues of user profiling and course structure will be addressed. The structure of the course will be designed so that it is be possible to present different content to each user and easier to author.

4.2. REQUIREMENTS

The objectives of this thesis are:

- The design of a dynamic and adaptive learning environment over the WWW that offers:
    - Adaptive delivery of the educational material to the students.
    - An assessment system that gives feedback to the system.
- The implementation of a prototype system that according to the design will be adaptive to the users' profiles. Example course material for the teaching of mathematics (trigonometry) in secondary education will be used. The prototype system will support dynamic creation of:
    - web pages containing the instructional material, according to the user's profile; and

- auto corrected tests for the assessment of the users.

Some of the requirements of a learning environment were discussed in chapter two and the requirements for the environment designed for this project will be based on these findings:

- Following the constructivists approach, the students must interact with the environment and actively participate in the learning process. The student must feel responsible for his/her own learning. Assessment and feedback must be available to the students. Motivation of the learners must be also achieved. The students must be presented with material appropriate for their level. Otherwise they might be discouraged and stop using the system.

- The system must provide sufficient material to cater for all the different learning styles. It must be possible for the students to choose whether they want to be presented with material best suited only for a certain style or all material available.

- Students must have control over their profiles. Profiling and description of the learning objects must follow the LTSC-IEEE standards. Profiling must provide the system with information necessary for adaptation techniques. The environment must be friendly in order for the adaptation offered to be beneficial. It is desirable that the system is able to communicate with other applications.

- Ease of authoring. As mentioned in chapter two, authoring an adaptive environment is usually a difficult task, especially if non-computer science people do it.

- Additional, mostly technological requirements are:
    - The efficient delivery of the material over the World Wide Web.
    - Media richness (use of multimedia and Java applets).
    - Scalability. The system must be capable of dealing with increased numbers of students and educational material.
    - Security. The information will be managed over the web increasing the need for security..

Whether the requirements were met or not will be discussed in following chapter.

4.3. ARCHITECTURE

An overview of the proposed architecture is shown in Figure 4.1. The doted lines represent the updates that the system is making in the profiles.

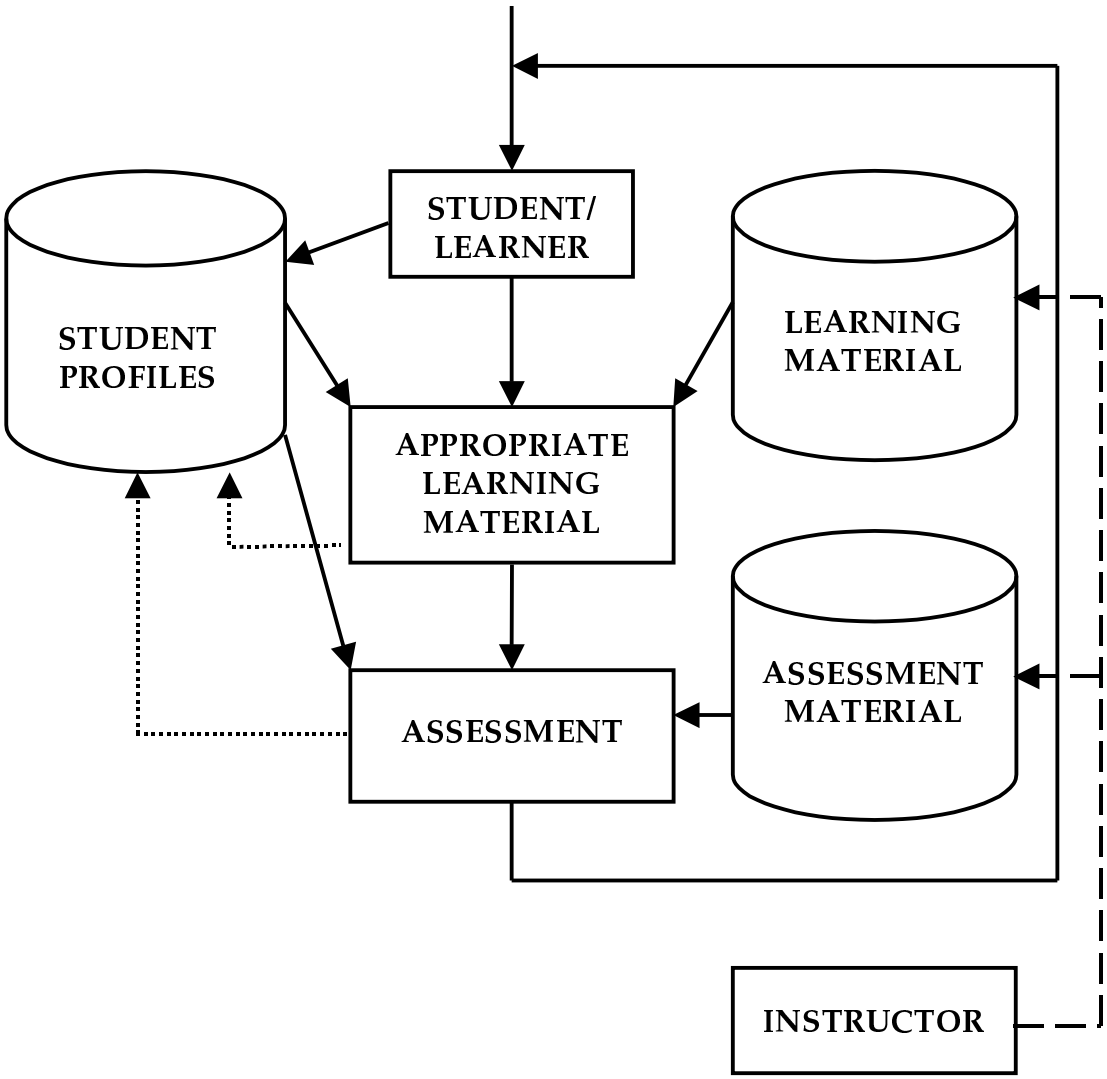


Figure 4.1 Overview of the System's Architecture

The appropriate learning material for each learner is displayed depending on his/her profile. The profiles can be set or changed by the learners themselves or by the system. The feedback for the changes in the profile comes from the results in assessment tests. The instructor is responsible for the learning and assessment material.

4.3.1 User Profiling

The system according to the requirements must be adaptive.

Users with different profiles will be presented with different content and with different course structure. Students can choose what profile is best for them making them responsible for their own learning. All user details are kept in a database.

The main details that make the system adaptive are:

- Learning style. The different learning styles as discussed in earlier chapter, can be accommodated by the use of different content for different learning styles. For the purposes of this thesis the learning style inventory according to the sensory intake of information was chosen. This is because this approach seems more appropriate for this project. The learning styles used are:
    - Auditory
    - Tactile/Kinaesthetic
    - Visual/Nonverbal
    - Visual/Verbal
    - All
- Difficulty Level. The level of difficulty depends not only on what the user wants but also to the progress in the coursework as it is monitored by the system. So there is the option to update the profile when there are enough results to correctly evaluate the student's performance. For the same reason as before it was decided that the system would not automatically make changes to a student's profile. The levels are:
    - Beginner
    - Intermediate
    - Expert
    - All

The "All" option in both cases is included for learners who wish to be presented with all the material available. This is in accordance with the approach of "teaching around the cycle".

There are many practical ways to assess the learning style of an individual with relatively good precision. This thesis does not intent to cover this material, so the use of an online questionnaire available on the www is proposed. Of course any other source can be used. The best though, would be if a specialist were advised.

An example scenario is shown in Figure 4.2. The profile of USER 1 shows that USER 1 is a *Beginner* and his learning style is *Auditory*. The requested page is made up of different modules. Each of the modules is characterised with the learning style and difficulty level that it is appropriate for. For USER 1 the modules that the page will contain are MODULE 1, MODULE 4 and MODULE 5. For a different user with a different profile e.g. difficulty level: *Expert* and learning style: *Tactile/Kinaesthetic*, only MODULE 5 would be used.

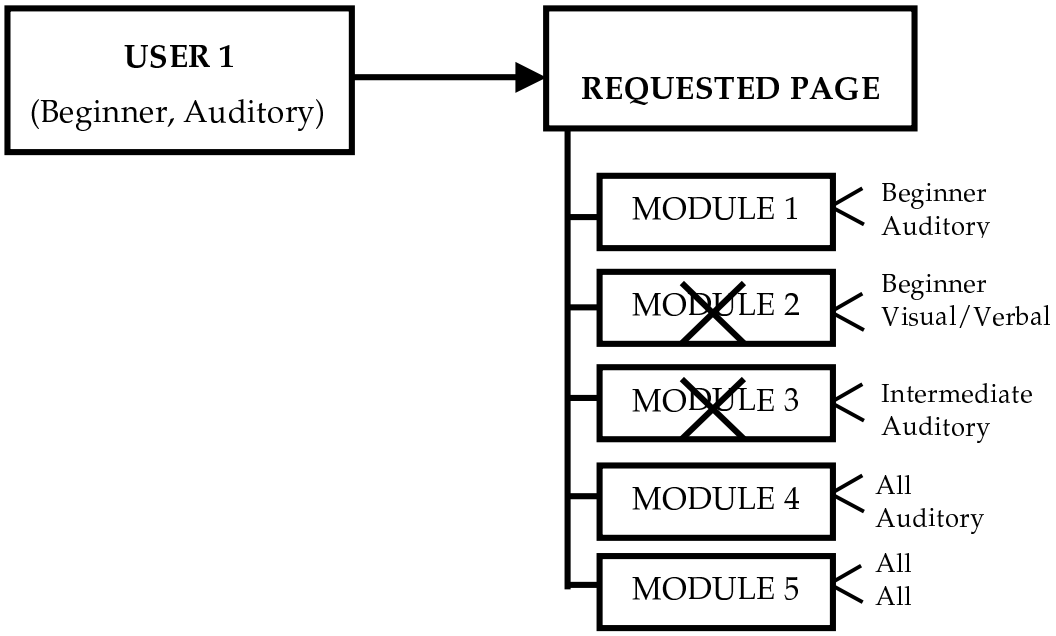


Figure 4.2 User Profiling – Scenario 1

If we take another example with USER 2 profiled as difficulty level: *All* and learning style *All*, we see that all the available modules will be used for the construction of the requested page. Any combination of learning styles and difficulty levels can be used and the instructor has to be careful when designing the course and especially when designing the specific pages from different modules.

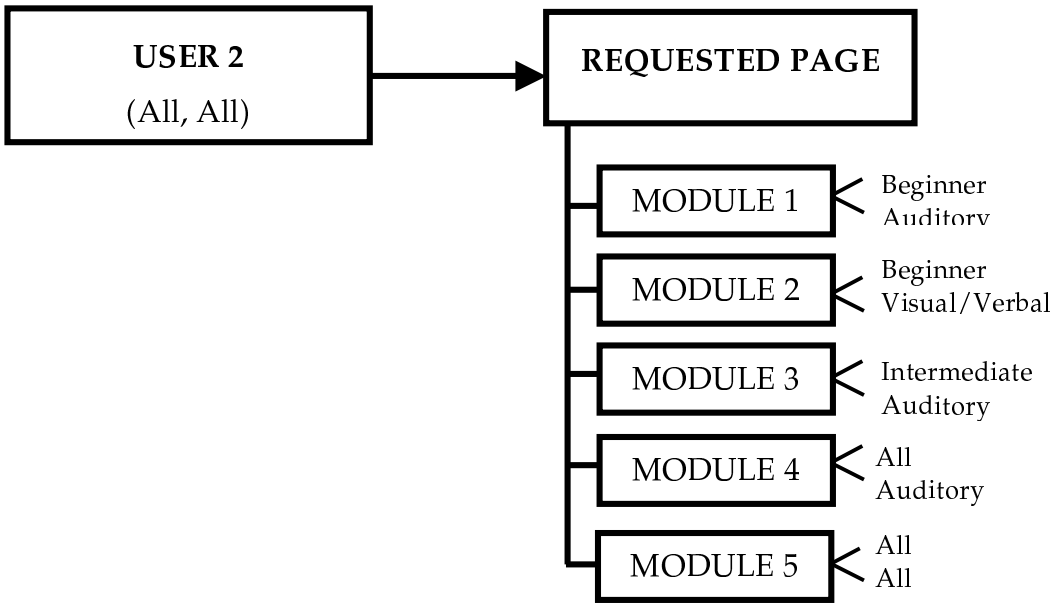


Figure 4.3 User Profiling – Scenario 2

Other profile details include:

- Requests for material. The material requested for reading by the student is stored together with the date and time requested and the amount of time that it was displayed for reading.
- Test results. After taking a test the associated unit and final score is stored in the database. The test results can be used to update the students' difficulty level.

The user himself sets some details whereas others are stored automatically by the system. User profile details set by the user are the Learning Style and Difficulty Level and the details automatically stored by the system are Requests of pages and Test results. The information gathered should be enough for the construction of a representative user model.

4.3.2 Course Structure

The instructor sets the course structure and it is basically the same for all students. So the section and units of the course are the same but the pages can be different. The partly static structure was chosen in an attempt to make the system easier to author. The material viewed by each individual can be different and this can affect the structure of the course that can be different for different users. An overview of the course structure can be seen in Figure 4.2.

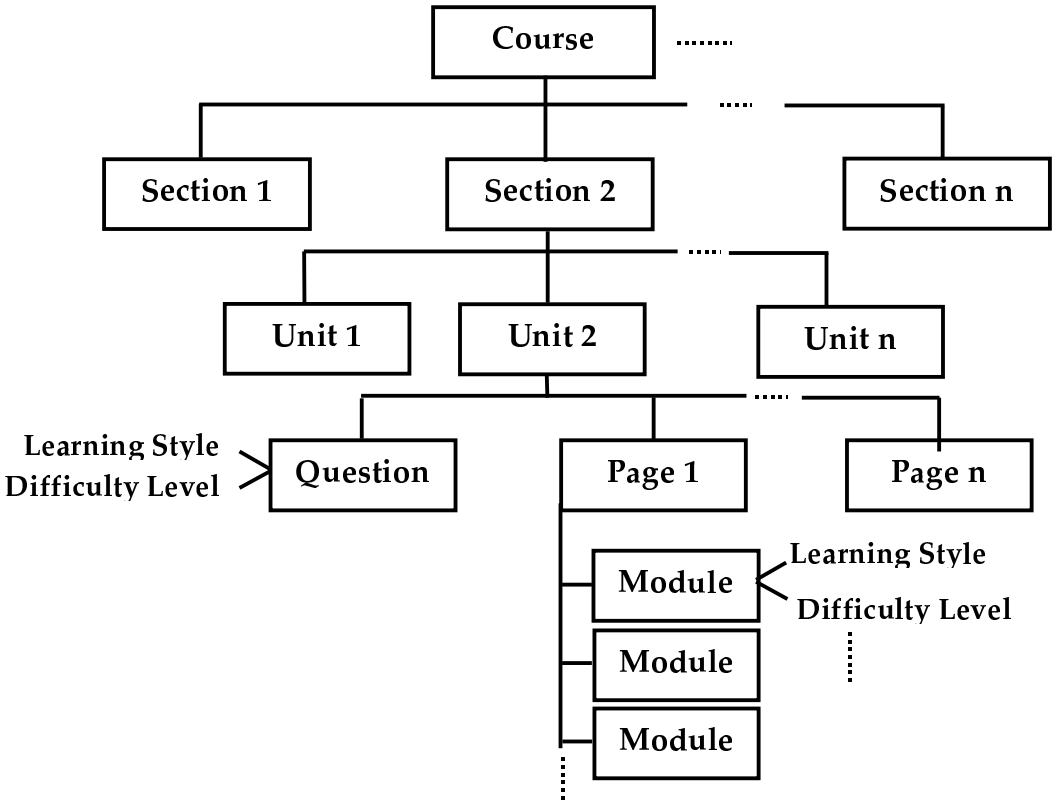


Figure 4.2 Overview of the Course Structure

The requested page is made up of modules appropriate for each user's learning style and difficulty level. A module can be an html or text page, an applet, audio/video file or a combination. Each page can have a prerequisite course unit. This means that when a user tries to view a page

with a prerequisite unit, a successful test on the prerequisite unit must be found before the user continues. Otherwise the user is advised to go back and pass the test.

In each page there are links to associated material. This material can be a page on the same topic designed for different learning styles than the one presented originally or any other page the instructor wanted to associate with the current page. In each page there is option for writing and saving notes related with that page.

4.3.3 Assessment

Questions are associated with course units and random tests can be generated for each unit. The learner will be prompted to take a test after the completion of a unit. There is no obligation for the students to take the tests on the grounds of making the student more responsible for his learning.

There can be different questions for each learning style and difficulty level. Questions can be multiple choice, True/False or fill-the-blank. Images, audio and video can be used in each question to cater for different styles. The instructor can associate each question with material and in the case of wrong answers further study material can be available. The goal of more feedback will be achieved with this feature. After a test, the result is stored and can be used for re-evaluating the user's difficulty level.

The difficulty of the tests depends on the student's profile and in particular their stated difficulty level. Learners can update their profile after the results in some tests. The results of each test are stored in the Student Profiles Database

4.3.4 Course Creation Interface

The interface must be simple and easy to use by non-computer experts. The Database can be populated over the WWW so that it is not necessary for the instructor to know in which machine the database is stored. Any external files (audio/video/html) are uploaded to the server. The instructor can construct a page with any text or html editor and then uploaded to the server for use within the system. The course administrator will be able to:

- Define the course structure (sections-units-pages);
- Add content (modules);
- Combine modules and construct pages for specific topics; and
- Adds questions for the generation of tests.

A module can be text, applet, picture, sound, video, or any combination. Each module is described as appropriate for a learning style and a difficulty level. Modules can be reusable and used in more than one page. The availability of the course management over the web makes the need for increased security stronger. Apart from the password protection, there is no other protection involved in this implementation.

4.4. DATABASE DESIGN

A Relational Database Management System (RDBMS) will be used to hold the course structure and material, the assessment material and the student's personal and performance information. The use of a database will make it possible to use the data from other applications. The data on the database will be retrieved from Java Servlets via SQL commands. The use of an RDBMS that can give the query results in XML format can be achieved.

The solution of the database for the storage of the student profile was preferred over the use of cookies. The reason is that this way the use of the system does not depend on the machine the student uses. Also the storage of the student's information in a database is valuable for analysing his behaviour and communicating this information to other applications.

The tables that will be used are:

- **Courses.** Contains the courses available.

  Fields: course_id (unique), course_subject.

- **Sections.** The sections of each course.

  Fields: section_id (unique), course_id, section_subject, section_order. The connection to the courses table is done with the common field course_id. One course can have multiple sections.

- **Units.** The units of each section.

  Fields: section_id, unit_id (unique), unit_subject, unit_order. The connection to the sections table is done with the common field section_id. One section can have multiple units.

- **Pages.** The pages (or topics) of each unit.

  Fields: unit_id, page_id (unique), page_subject, page_order, prerequisite_unit. The connection to the unit table is done with the common field unit_id. One unit can have multiple pages. The prerequisite_unit field can relate the particular page to a unit in the unit table.

- **Pages_modules**. This table contains the modules that make up a course page.

  Fields: page id, module_id, module_order (the order in which the page modules must be displayed).

- **Module_info.** The actual content of each module is stored in this table.

  Fields: module_id (unique), module_subject, module_info, content_file, type_descriptor, library, file_name, width, height.

- **Module_meta_info.** The meta-information necessary to describe a module is kept in a separate table.

  Fields: module_id (unique), topic, learning_style, difficulty_level.

- **Questions.** All questions used for assessment tests are stored in this table.

  Fields: question_id (unique), quiz_id, section_id, unit_id, page_id, question_type, question_text, question_picture, question_file, question_applet, applet_library, applet_width, applet_height, choice1_text, choice2_text, choice3_text, choice4_text, answer.

- **Questions_meta_info.** This table contains the meta-information that describes each question.

  Fields: question_id (unique), difficulty_level, learning_style, related_page. The related page is used to present related to the question study material, in case the student gives a wrong answer to the question.

- **Students_personal_info.** The learners' personal information is stored in the table. The personal information is not important to the learning process. It is used to validate the user name and password entered.

  Fields: user_name, user_passwd, full_name, address.

  More fields can be actually added to this table depending on the will of the course administrator.

- **Profiles.** The details that describe the learning

preferences of a user. The information in this help find the appropriate for each user learning material.

Fields: user_name (unique), course_id, learning_style, difficulty_level, logout, bookmarked_page. The field logout states whether the user is using the database at the moment or not. The field bookmarked_page shows the last page visited by the student.

- **Performance_info.** The results in all the tests taken are stored in this table.

  Fields: user_name, section_id, unit_id, page_id, score.

- **Personal_notes.** The users can enter their personal notes in each page they view. These notes are kept here.

  Fields: notes_id, user_name, notes, page_id.

- **User_trace.** The surfing habits of the users can be stored here.

  Fields: user_name, page_id, visit_date.

- **Instructors.** The details of the users that have the rights to manage the database.

  Fields: user_name (unique), user_passwd, full_name.

An overview of the tables' structure and the relationships is shown below

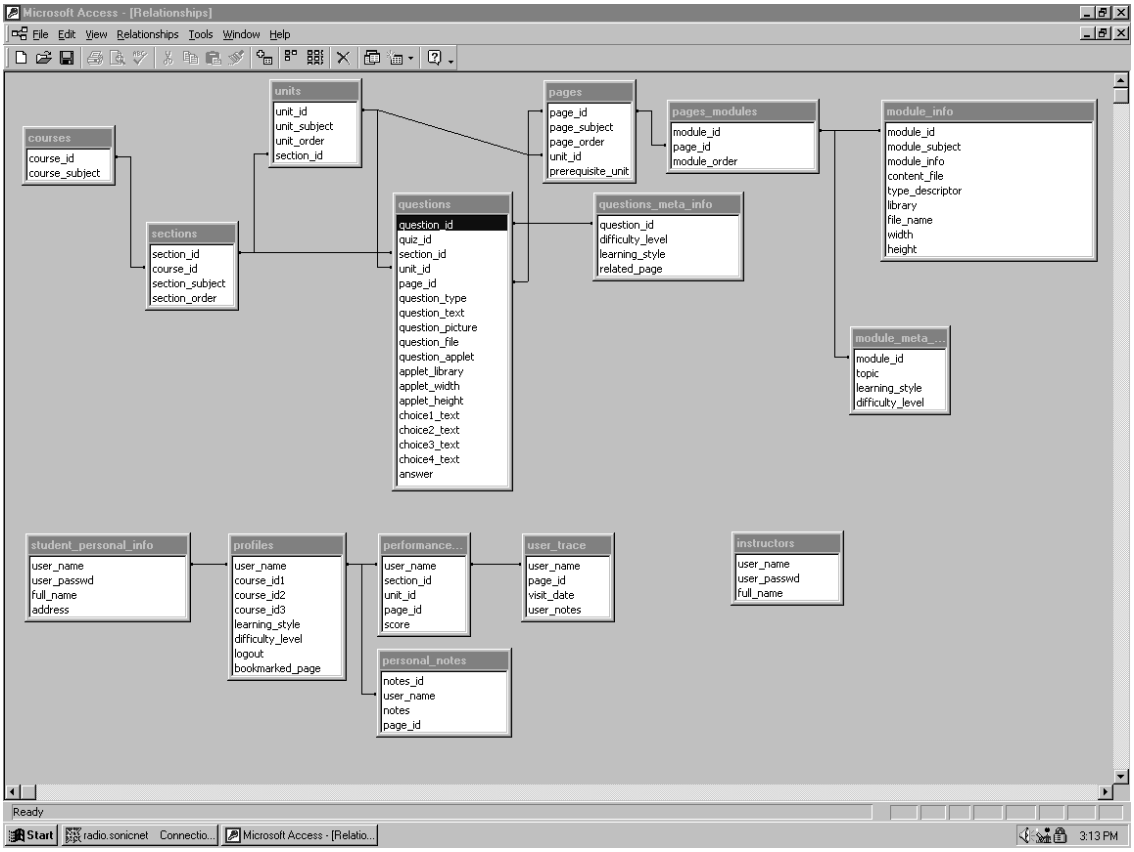


Figure 4.3 Database Structure and Relationships

4.4.1 User Profiling

The learning identity of each student will be stored in the database. The performance in each test, the requested material and the time dedicated to each page can be used to identify the learning behaviour of each student. This will be used to make the system adapt to the user's habits and needs. The personal information according to the IEEE standards set by PAPI must be separate from the performance information.

4.4.2 Instructional Material

The instructional material stored in this database will be structured in tables related to each other with a key field. There are separate tables that hold information for the available courses, the sections, the units and

the pages of each unit. The modules are stored in two other separate tables. The first table contains the basic information for each module while the second table contains the meta-information. The meta-information is used to further describe a module and is its educational identity. Meta-information includes the topic for which the module is useful and the learning style and difficulty level each module is appropriate for. For each module applets, the instructor can enter text, html, or audio/video files. Only a reference to a file will be stored in the database and not the file itself.

4.4.3 Assessment Material

A pool of test questions will be available for the creation of assessment quizzes. In each question, the instructor can use in addition to text, images, sound and video. The types of the questions are multiple-choice questions (M.C.Q.), True-False questions or questions where the student must answer entering a phrase or word. The importance is that the questions must be automatically corrected by the system without the need for the instructor.

Questions are associated with a section, unit or page. In this way, tests for any of these parts of the course can be generated. Questions, just like page modules are stored in the database with the use of two different tables: one for the question information and one for the question meta-information. The meta-information table contains the learning style and difficulty level that the question is targeting. It also contains an associated page. This is used as recommended studying in the case the learner answers incorrectly.

4.5. SUMMARY

In this chapter the design of the adaptive learning environment was introduced. The design was discussed under three subsections, the requirements that were set, the model of the environment and the

database design. The model includes details for the student profiling, the course creation and the material presentation. The strategy for the assessment of the students and the interface for populating the database with the course content are also included. Two basic user details are used for making the system adaptive: the user's learning style and difficulty level. All details for the users, profile, personal and performance information, the course material, and the assessment material are stored in a relational database.

5. IMPLEMENTATION

5.1. INTRODUCTION

In the previous chapter the system architecture was outlined. This chapter discusses the implementation of the prototype. The prototype will be implemented and tested, mostly from a technological point of view. The pedagogical issues will be taken into consideration but will be tested and evaluated thoroughly from educators taking the MSc course "IT in Education", in Trinity College. Therefore the prototype must be robust and fully functioning enabling the instructors to use it without requiring detailed knowledge of the computer technology issues (e.g. databases).

5.2. TECHNOLOGY

The system will be available over the World Wide Web. The dynamic generation of the web pages will be done with Java Servlets. The material for the construction of the pages will be taken from a database. The functionality in the html pages will be improved with the use of JavaScript. The material presented can be text/html, applet, audio or video and the environment must cater for all formats. Apache server was used as the server for the application.

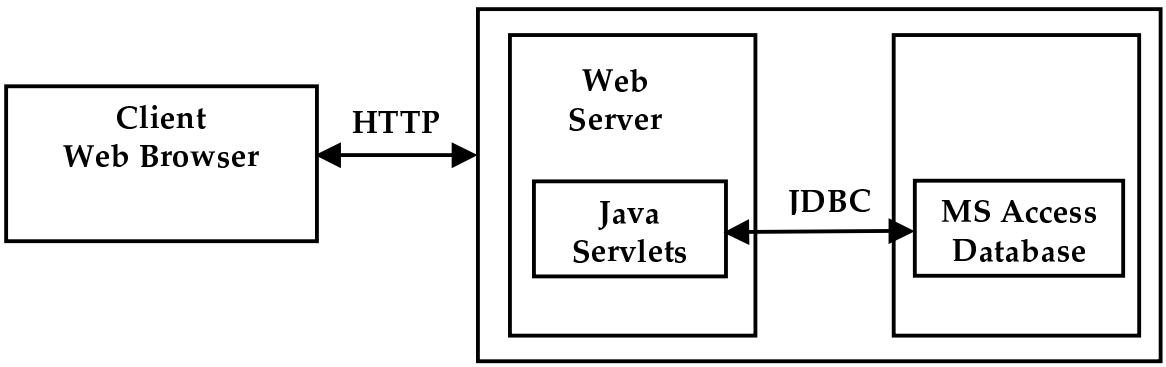
5.3. DATABASE ORGANISATION

Microsoft Access RDBMS is the choice for the storage of the course material. Access was selected over other popular databases like ORACLE, because of its friendlier and most common environment. Although, as set by the requirements, it is not necessary that the instructors have knowledge

on specific computer science issues, there has to be however, the option of most active involvement in the course creation and management of the material. ACCESS offers that, as it is easier to use by non-computer experts, and more widely available. The drawback is that ACCESS does not support XML. The exact database structure with all the fields and their type is listed in Appendix A.

5.4. ARCHITECTURE

The Database and Web server are hosted on the same server but can be on different servers as well. Generation of all html pages is done by Java Servlets. The only html pages that exist are the page for the input of the user name and password. All data that Servlets use are stored in the database and JDBC is used to connect to the database. The overall



architecture is shown in Figure 5.1.

Figure 5.1 System's Web architecture

The use of JDBC makes easier the manipulation of the database and the creation of the html pages with the use of Java Servlets.

5.4.1 Servlets

The aim to have an adaptive environment, with content that is generated dynamically for each user, is achieved with the use of Java Servlets. The Servlets connect to the database and retrieve the appropriate material.

GET and POST methods are used for sending data to the Servlets. The POST method is used mainly when sending data from html forms with the use of buttons. In most cases, though, the use of GET was preferred because it allows calling the Servlet from a link without the use of a button.

5.4.2 Course Appearance

In Figure 5.3 we can also see the menu that helps navigation within the learning environment. The options on the top of the page are:

- *Home Button*: The welcome page is generated
- *Profile*: The page for the control of the user's own profile
- *Contents*: A table of contents with the available learning material
- *Assessment*: A table of contents with the units with available questions to generate a test
- *Bookmark*: Brings the last page the user was reading
- *Links*: A page with links related to the course. For the prototype this page holds links to teaching material and online courses related with mathematics and especially Trigonometry and Geometry.
- *Logout*: When the user logs out the database is updated so that the instructor knows whether the user is online or not. It can also be used for security reasons.

Other features that can be found at the bottom of each page are:

- *Top*: Takes the user to the top of the page
- *Help*: Help on the use of the system and any other guidelines can be included in the help page
- *About*: Information about the environment, the project and the course administrators
- *Contact us*. The email of the course director or lecturer.

The generation of the html code for every page in the system is done from the Java Class *PageHeadFoot.java*.

5.4.3 User Authentication

The learners that wish to use the environment must log in entering their user name and password (Figure 5.2) provided by the course administrator. The user, after entering the user name and password required, is authenticated and can use the environment. The welcome page (Figure 5.3) is created. It presents the user with the options to view and change part of his profile, to view the learning material or to take an assessment test.

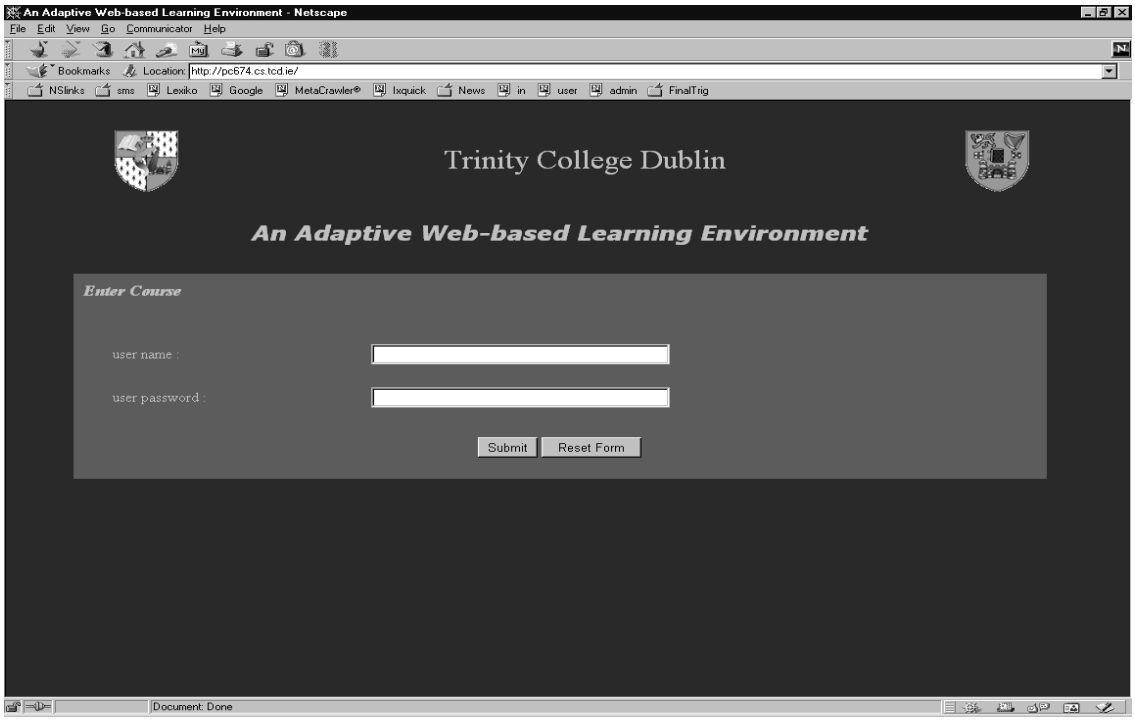


Figure 5.2 Screenshot of the details entered for authorisation

Home Button System Navigation

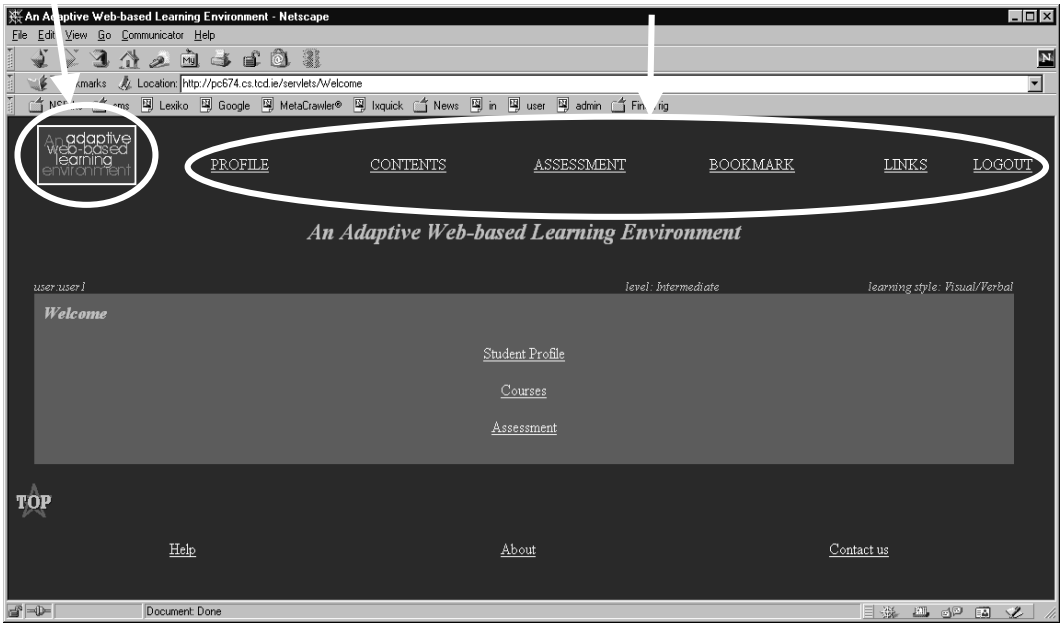


Figure 5.3 Screenshot of the welcome page

5.4.4 User Profile

Once the user selects to view the profile page, the student details are extracted from the database. Figure 5.4 shows what the screen looks like.

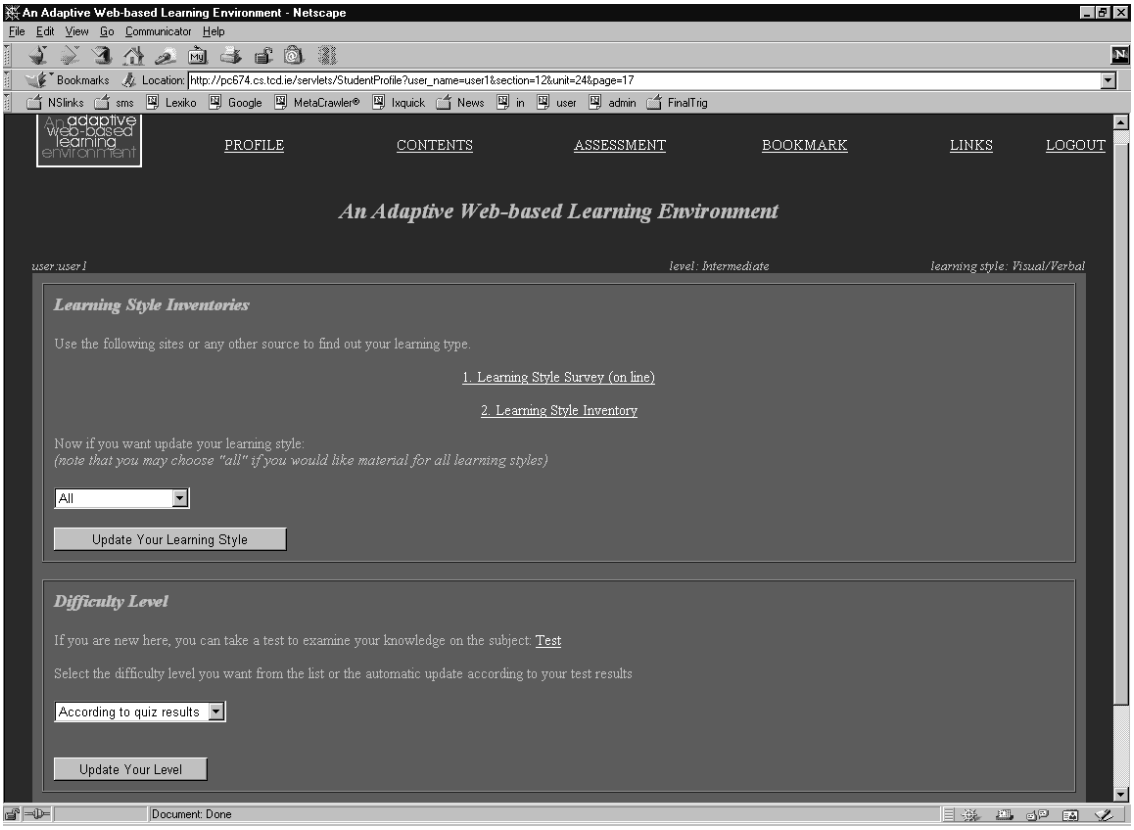


Figure 5.4 Screenshot of the profile page

The user can select the preferred learning style and difficulty level from drop down menus. The learning style can be assessed by other sources than this prototype. Relevant links are provided here. For the assessment of the difficulty level the user can choose the one that is believed most suitable. The difficulty level can be updated automatically by the system if the user selects from the drop down menu, the option *According to test results*. In order for this option to work properly a few tests must have been taken

from the student. If there are no results or it is the first time on the system a test can be generated. The test is made up of general questions on the course, that are described as appropriate for the difficulty level *Beginner*. The result is a suggestion as for what difficulty level the user must choose.

5.4.5 Course Contents

The course structure for the student is selected. The result is the course structure: sections, units and the available pages-topics for the user's profile. The learner can select to view the material for a topic. An example page is shown in Figure 5.5

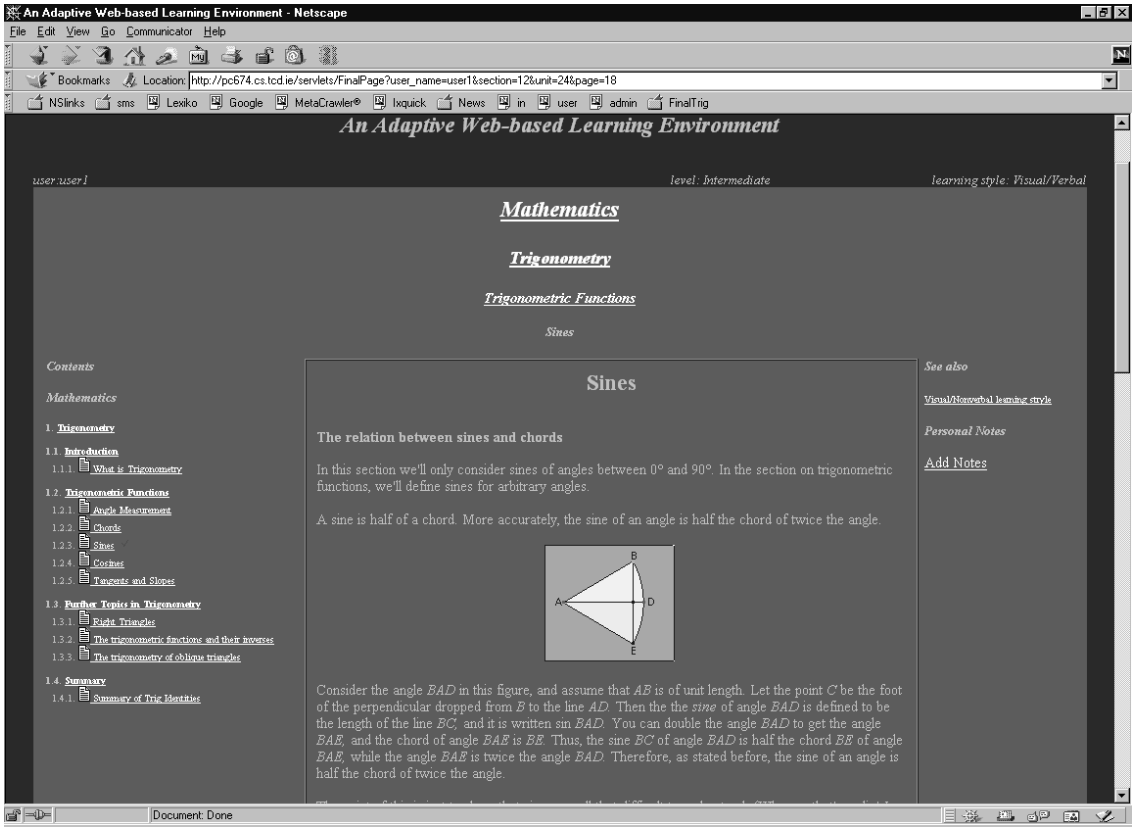


Figure 5.5 Screenshot of a page with material for a topic

In order for the page to be created, the user's profile will be extracted allowing selection of only those modules described in the meta-information with the same learning style and difficulty level.

The page structure includes: the learning material on the centre, on the left hand side of the screen the course contents serving as the roadmap for the students, and on the right hand side related content. For displaying the related content, modules for this page that are not indented for the profile of the user are selected. The purpose of this is to present the user with alternative styles, something that sometimes might be proved stimulating and beneficial as mentioned in chapter two.

Another feature of the application is that it allows the user to add personal notes on each page. The notes are stored in the database. Notes can be added and deleted many times. This feature is implemented with the use of JavaScript.

5.4.6 Assessment

A list of all the units available in the course is shown to the user and upon request a quiz is generated. The questions for this unit, which are also, appropriate for the profile of the learner, will be presented in a random order each time. Ten questions at the most are currently used for the tests. The submitted answers will be evaluated and the results will show all the questions, the correct or wrong answers and a link to additional material.

An example test is shown in Figure 5.6

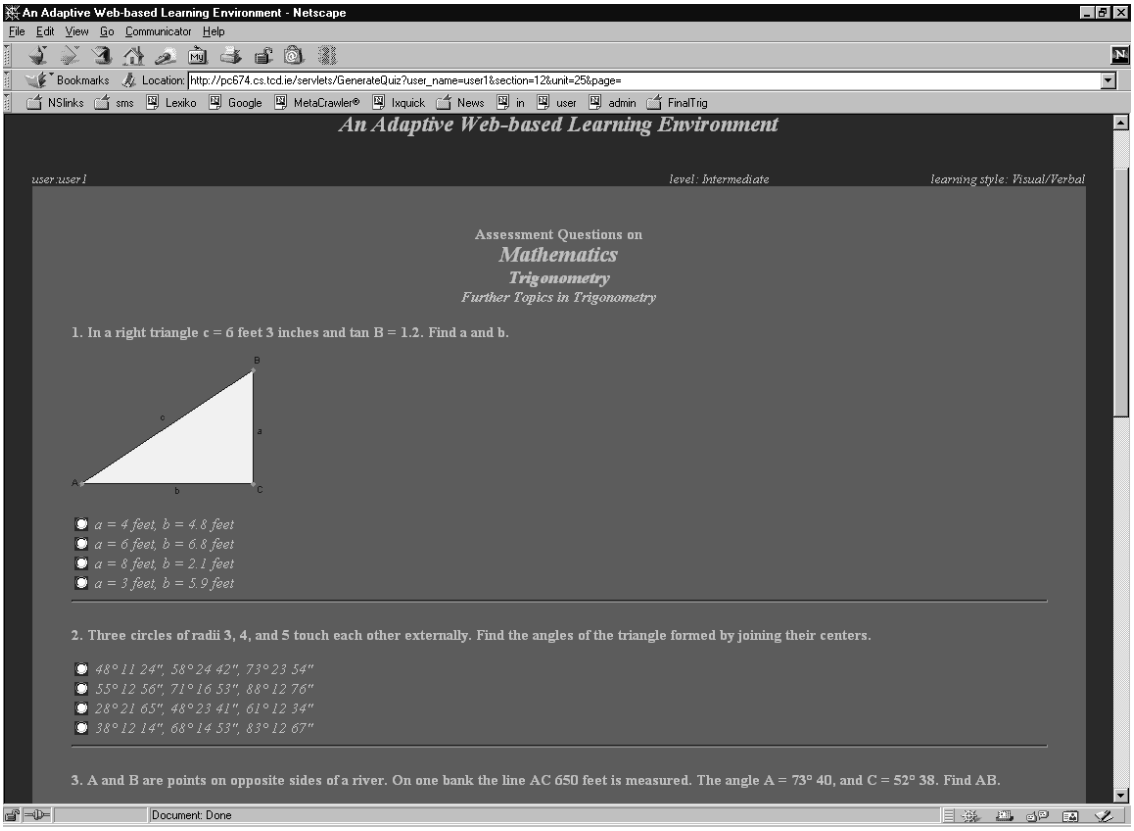


Figure 5.6 Screenshot of an example test

5.5. SUMMARY

This chapter dealt with the implementation issues of the prototype. The next chapter will deal with the evaluation of the environment implemented and according to the requirements set in chapter four.

6. EVALUATION

6.1. INTRODUCTION

The objectives of this dissertation were to explore the use of adaptive technologies in a learning environment and build a prototype that will be used by non-computer science people for further evaluation. This chapter will discuss whether these goals and all the requirements set earlier in this report were met.

6.2. EVALUATION METHODOLOGIES

In their paper on the evaluation of Adaptive Hypermedia Systems (AHS), De Bra *et al.* [28], reviewed the evaluation of some AHS a) on adaptive presentation and b) on adaptive navigation support. Pilot testing of the applications was used as an evaluating method.

Mark & Greer [38] in their research in evaluation methodologies for Intelligent Tutoring Systems (ITS) distinguish between formative and summative evaluation. In formative evaluation a system is examined during the development in order to correct problems and perform necessary modifications. On the other hand, summative evaluation has more to do with the construction, behaviour, or outcomes of a completed system. Because of the complexity of an ITS not all evaluation techniques are applicable. For a formative examination a criterion-based assessment can be appropriate. Informal techniques are less appropriate for a summative evaluation. Sensitivity analysis however, may have potential for evaluating adaptation of an ITS.

In criterion-based evaluation the system is examined in order to determine the degree to which the requirements and specifications were met. The care with which the criteria have been developed is critical.

With sensitivity analysis a system is examined to see how responsive its behaviour is to differences in the information it receives.

Unfortunately evaluation techniques, which focus on the educational effects of this system were not possible to be performed. A pilot testing would be very useful in determining the effectiveness of the system as a teaching medium. This will be the goal of a possible future project. The prototype will be used and evaluated educationally from the MSc in "IT in Education" class. Instead, the criterion based evaluation and the sensitivity analysis methodologies will be used for evaluating this system's architecture and behaviour.

6.3. EVALUATION OF THE THESIS OBJECTIVES

6.3.1 Constructivists Approach

A number of features added in this project were according to the constructivists approach. Interaction and active participation of the students will hopefully be achieved with the use of technologies like multimedia and Java Applets. The student is actively participating in the learning process by choosing his own learning profile. This alone makes the students think about their individual ways of learning making them see the process from another aspect. Assessment was referred as a way of motivating and helping students learn. Assessment is incorporated in the prototype built. Test with random questions are generated and feedback is available in case of a wrong answer. Motivation is also achieved because the assessment results can be used to change the student's profile. This

will encourage those who do well in test. Tests however, are not obligatory and neither is the change of profile so that the students don't feel the pressure and stress of examinations.

6.3.2 Adaptation

The different learning styles used for this thesis were reviewed in Chapter Two. The different preferences and appropriate strategies were also mentioned. The use of applets, audio, video and images is believed to give the basis for a successful use of the environment. It is up to the summative evaluators to decide whether the educational impact of this environment to the students will be beneficial or not. The goal to provide different content to different type of learners was achieved.

The requirement "teaching around the cycle" was met as the learners are free to choose a learning style or difficulty level but can also choose "*All*" and be presented with material for all styles. This however might not be proved as beneficial in practice. The pages generated might not have a perfectly logical structure and repetition of terms and information in different formats might be tiring. Instead, the "*See also*" part of the page (Figure 6.3), which offers pages on the same topic but for different learning styles, can be used.

Material for different levels can be presented to the learners making the implemented environment at worse less discouraging and at the best motivating.

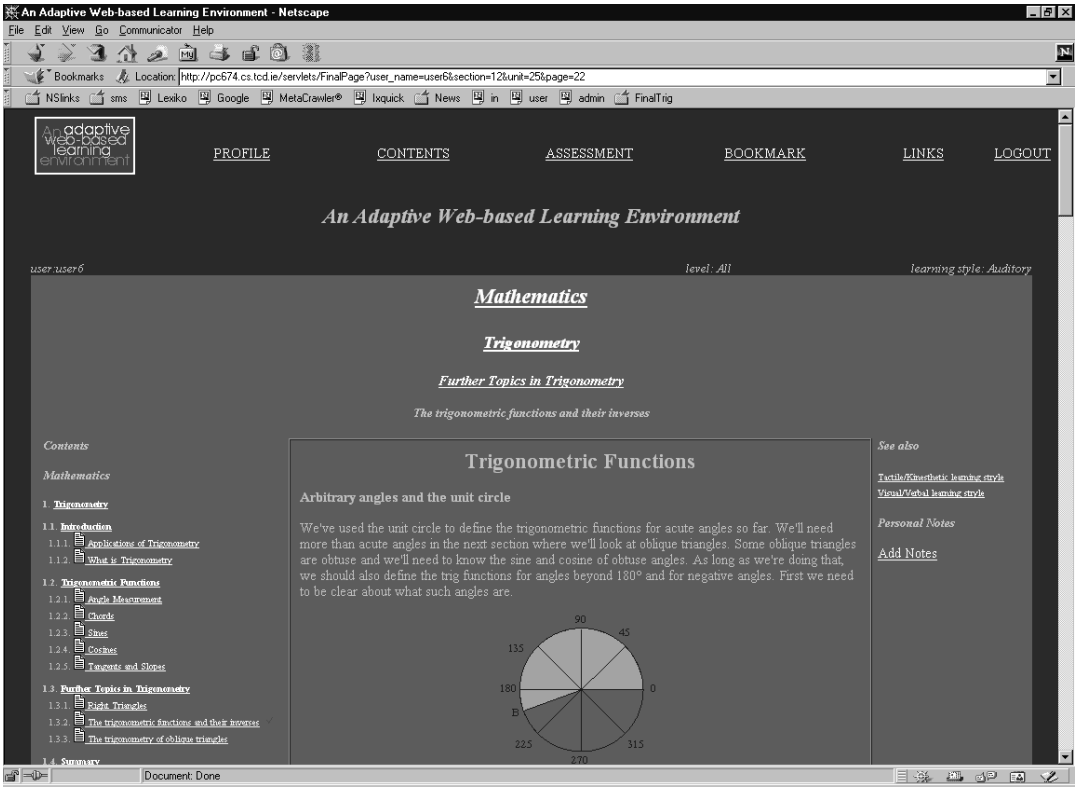


Figure 6.1 Availability of Content for Different Learning Styles

6.3.3 User Profiling

The personal information of students is kept in a different table than the performance information. Assessment results and requests for pages are being recorded, providing information on the behaviour of the learners and the progress they make. The profiles are not changed automatically by the system but only after the learner ask for an update. The record structure of the database tables is following the PAPI standard

The need, however, to communicate with other applications is only met with the use of a Relational Database and its availability for other applications to use. The desire to investigate the use of XML was not met. It would be very interesting to do, as XML will be more widely used in the near future.

6.3.4 Course Content Creation

The implementation of content creation interface, proved to be a very challenging part of the prototype. In Chapter Two it was recognised from the literature survey as such. An effort to make it as simple as possible is believed to have succeeded up to a point. It remains to be proved in practice.

The process of designing pages on the same topic for different learning styles is complex enough. If the course administrator or lecturer designs the pages carefully, then add the different modules, and then construct the pages, it is believed that the work will be comparatively straightforward. The need for further improvement however, is highlighted.

The requirement for additional security was not addressed in this dissertation. Security was only added in the form of user/administrator authentication. This is clearly not enough and further improvements are necessary before the prototype is usable.

6.4. SUMMARY

This chapter presented a brief discussion on evaluation methodologies used for adaptive educational systems. An evaluation was attempted based on the requirements discussed in Chapter Two. Some limitations of the design and some concerns were introduced and will be discussed more thoroughly in the next chapter.

7. CONCLUSIONS

7.1. INTRODUCTION

This chapter will summarize this dissertation and will present overviews of the theoretical background and the system, which was designed. Proposed future work, conclusions and comments on limitations and problems encountered throughout this project, will be discussed.

7.2. THEORY OVERVIEW

The supporting theory on building online environments was introduced in Chapter Two. The efficiency of the web as a medium for delivering education was discussed with concern to pedagogical issues. The importance of constructivism in education was outlined. The theory of learning styles was briefly discussed and the approach this thesis took was introduced. The choice of a particular learning style inventory was reasoned and the benefits from learning styles and their role in adaptive environments was part of this discussion.

Assessment is an important part in the educational process and as such it was used as part of the adaptation model used for this dissertation. The literature was reviewed for the state of the art, in the area of adaptive hypermedia, user profiling and designing online or web-based learning environments.

7.3. SYSTEM OVERVIEW

The Figure 7.1 present an overview of the system designed.

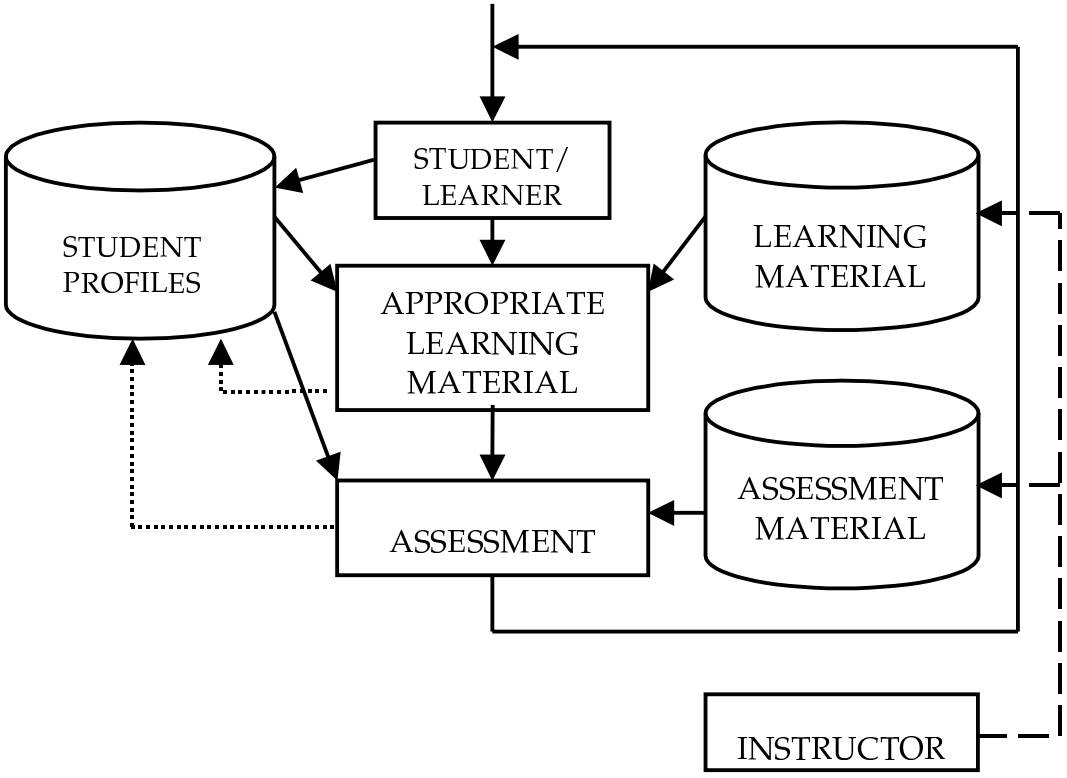


Figure 7.1 Systems Overview

The designed system is available over the www. The instructor is responsible for the population of the database with educational material. Student have profiles based on their learning styles, difficulty level and assessment information. The environment adaptively presents the course content according to the students' profile. Assessment material is available in auto-corrected questions. The students have control over their profiles.

A relational database is used for the storage of the profiles and of all the material. Pages will the material, are generated on the time of the request. Pages are made up of modules. Modules can be html, text, applets or multimedia files. The use of educational applets is a key feature in the system.

7.4. IMPROVEMENTS - FUTURE WORK

In the previous chapter the system was partly evaluated and some of the limitations and problems faced during the implementation, were mentioned.

The design of different pages on the same topic, for different learning styles was recognised as a complex task. Further research and possible projects that tackle with this problem will be helpful to the development of better AHS. Additionally, the issue of security needs further development, as it wasn't addressed properly by this project.

Course material must be carefully designed and more alternative ways of presenting information must be used. Applets seem to be a highly useful format that can be used for a series of learning styles and difficulty levels. The development of more applets and of more material must be the first step before evaluating the educational impact of such an environment. Further research on what is appropriate for each learning style is essential for an adaptive environment.

An educational system succeeded its goals if the students that use it benefit from it. A proper evaluation can prove whether a system achieved its goals and to what extend.

The use of XML should be considered for addressing issues like the communication and cooperation with other applications. XML should also be considered for improving the adaptive technologies and in presenting adaptive content. Another domain that XML is used is the description of the educational objects. Therefore XML might be the solution to the

complexity in designing course material for adaptive systems.

7.5. CONCLUSIONS

To the extend that it was possible, this thesis proved that it is possible to design and implement a web-based learning environment that is adaptive to the student's learning styles and difficulty levels. The design presented in Chapter Four and the implementation in Chapter Five, where evaluated in the previous chapter. In this chapter some improvements to the system were proposed. Although the system seems to satisfy the basic requirements set in this dissertation the need for evaluation of its educational impact is critical.

In general, adaptive learning environments seem to have a lot of potential. There might be different directions in adaptation techniques but overall, adaptation can be useful in teaching over the Web where the learners can be people with different goals and knowledge. In particular, the areas that adaptation is used and will be more widely used in the future are: education, online training and online help.

The result can be systems that can be used by a big variety of learners. This will have an immense impact in the quality or even speed of learning. Adaptation based on learning styles that was proposed in this thesis might motivate people in using an environment and gain from it. The different preferences, needs, aims and levels of users can all be catered by a system. Moreover, the availability of the Web means that someone can learn at his/her own pace and when he/she feel like it.

Research, not only for adaptive presentation and navigation but also for assessment and other parts of a learning environment will contribute to

more complete adaptive learning environments.

Adaptation can also be used in a number of Web applications, providing navigation support making the Web more compact and friendlier for the users. Research in the area of Artificial Intelligence (AI) can really increase the possible applications of adaptation techniques, providing with new ideas and with more detailed and accurate profiles. All things considered, the future of Adaptive Hypermedia Systems seems to be very promising.

APPENDICES

A. DATABASE STRUCTURE

1. Courses

Course_id	AutoNumber
Course_subject	Text

2. Sections

Section_id	AutoNumber
Section_subject	Text
Course_id	Number
Section_order	Number

3. Units

Unit_id	AutoNumber
Unit_subject	Text
unit_order	Number
Section_id	Number

4. Pages

Page_id	AutoNumber
Page_subject	Text
Page_order	Number
Unit_id	Number

5. ***Pages_modules***

Page_id	Number
Module_id	Number
Module_order	Number

6. ***Modules_info***

Module_id	AutoNumber
Module_subject	Text
Module_info	Text
Content_file	Text
Type_descriptor	Text
Library	Text
File_name	Text
Width	Number
Height	Number

7. ***Modules_meta_info***

Module_id	Number
Topic	Text
Learning_style	Text
Difficulty_level	Text

8. ***Questions***

Question_id	AutoNumber
Quiz_id	Number
Section_id	Number
Unit_id	Number
Page_id	Number

Question_type	Text
Question_text	Memo
Question_picture	Text
Question_file	Text
Question_applet	Text
Applet_library	Text
Applet_width	Number
Applet_height	Number
Choice1_text	Text
Choice2_text	Text
Choice3_text	Text
Choice4_text	Text
Answer	Text

9. Questions_meta_info

Question_id	Number
Related_page	Number
Learning_style	Text
Difficulty_level	Text

10. Modules_meta_info

Module_id	Number
Topic	Text
Learning_style	Text
Difficulty_level	Text

11. Student_personal_info

User_name	Text

Usaer_passwd	Text
Full_name	Text
Address	Text

12. Profiles

User_name	Text
Course_id	Number
Learning_style	Text
Difficulty_level	Text
Logout	Text
Bookmarked_page	Number

13. Performance_info

User_name	Text
Section_id	Number
Unit_id	Number
Page_id	Number
Score	Number

14. Personal_notes

User_name	Text
Notes_id	Number
Notes	Memo
Page_id	Number

B. LIST OF SERVLETS

1. For the implementation of the teaching model:

- BookmarkedPage:

  Finds the last visited page and takes the user there.
- CustomPage:

  Selects all the available pages for a particular unit. If one is selected it calls the Servlet FinalPage.
- CustomeUnits:

  Selects all the available units for a particular section. If one is selected it calls CustomPage.
- DefineQuiz:

  Lists available units and when one is selected it calls the Servlet GenerateQuiz.
- EnterCourse:

  Displays all the available sections for the course the student is enrolled.
- EvaluateProfileQuiz:

  Called from the GenerateProfileQuiz Servlet and is used for the evaluation of the user's answers and to propose the difficulty level appropriate to the user's knowledge on the subject.
- EvaluateQuiz:

  It evaluates the answers the student gave to an assessment test and stores the result to the student's performance information table.
- FinalPage:

  One of the main Servlets used in the application. It will display the material for a specific topic. First it will select the appropriate modules for the user and then it will find material for different profiles. It will also save and display any notes the user wants to keep.

- GenerateProfileQuiz:

  It will search the database for questions suitable for a beginner and will assemble a test. It is called from the StudentProfile Servlet.
- GenerateQuiz:

  This Servlet selects the questions suitable for the user that requested the test and displays a test with ten randomly ordered questions. The Servlet EvaluateQuiz is processing the submitted results.
- Links:

  Displays the links to other Internet sites with information relevant to the course. The links are written from the html file *all_links.html.*
- LogOut:

  When the user logs out the database is updated.
- RoadMap:

  Displays the table of contents for the course.
- StudentProfile:

  Allows the user to control and change his profile. If the user chooses to change either the learning style or the difficulty level, the Servlet UpdateStudentProfile will be executed.
- UpdateNotes:

  This Servlet is saving any notes or comments the user wants to save for a particular page.
- UpdateStudentProfile:

  It will update the learning style and difficulty level according to what the student stated. If the update of the difficulty level according to test results was chosen, it will select the results in test for the user and after finding the average score it will either advance the student to the next level or back to the previous level.
- Welcome:

  It will create the first page displayed after a successful log in.

2. ***Servlets for the implementation of the course creation interface:***

- Maintenance:

  Executed from the maintain.htm page and accepts as parameters the user name and password. It evaluates the in the instructors table of the database and allows the user to continue changing the course structure/content or not.

- ManageCourses:

  Allows the course administrator to change course structure or add material to it.

- ManageQuiz:

  This Servlet helps the course administrator to add assessment questions to the database.

- ManageUsers:

  This Servlet helps the course administrator to add users to the database.

- UpdateCourses:

  This Servlet will carry out the actual changes of the course structure/content in the database.

- UpdateUsers:

  This Servlet deletes or add users in the database.

3. ***Java classes with methods used from all above listed Servlets:***

- PageHeadFoot
- UserDtls

BIBLIOGARPHY

[1] B. Dillon, "Courseware on the fly," in *Department of Computer Science*. Dublin: Trinity College, 1998.

[2] J. W. Keefe, "Learning Style: An overview," *NASSP'sStudent Learning Styles:Diagnosing and prescribing programs*, pp. 1-17, 1979.

[3] W. B. James and D. L. Gardner, "Learning Styles: Implications for Distance Learning," *New Directions for Adult and Continuing Education*, pp. 19-32, 1995.

[4] C. McLoughlin, "The implications of the research literature on learning style for the design of instructional material," *Australian Journal of Educational Technology*, vol. 15, pp. 222-241, 1999.

[5] R. Riding and C. I., "Cognitive Styles: An overview and integration.," *Educational Psychology*, vol. 11, pp. 193-215, 1991.

[6] D. Robotham, "The application of learning style theory in higher education teaching," , 1999.

[7] R. Felder, "Matters of Style," *ASEE Prism*, vol. 6, pp. 18-23, 1996.

[8] S. Montgomery, "Addressing Diverse Learning Styles Through the Use of Multimedia," .

[9] P. Gentry, "Perceptual Learning Style," *LinguaLinks Literacy Bookself*, vol. Notes on Literacy, 1990.

[10] C. Jester and S. Miller, "DVC Learning Style Survey for College," : Diablo Valley College, 1999.

[11] M. O'Reilly and K. Patterson, "Assesing learners through the WWW," , Australia, 1998.

[12] M. Thelwall, "Computer-based assesment: a versatile aducational tool," *Computers & Education*, vol. 34, pp. 37-49, 2000.

[13] H. Ogata, C. Feng, Y. Hada, and Y. Yano, "Online markup based language learning environment," *Computers & Education*, vol. 34, pp.

51-66, 2000.

[14] R. Barger and J. Barger, "Teaching and Learning History of Education Through the World Wide Web," presented at International Standing Conference for the History of Education, University of Louvain, Kortrijk, Belgium, 1998.

[15] S. McNeil, B. Robin, and R. Miller, "Facilitating interaction, communication and collaboration in online courses," *Computers & Geosciences*, vol. 26, pp. 699-708, 2000.

[16] N. Papaspyrou, S. Retalis, S. Efremidis, G. Barlas, and E. Skordalakis, "Web-based teaching in software engineering," *Advances in Engineering Software*, vol. 30, pp. 901-906, 1999.

[17] V. Makrakis, S. Retalis, A. Koutoumanos, N. Papaspyrou, and M. Skordalakis, "Evaluating the Effectiveness of an ODL Hypermedia System and Courseware at the National Technical University of Athens: A Case Study," *J.UCS*, vol. 4, pp. 259-272, 1997.

[18] D. Mioduser, R. Nachmias, O. Lahav, and A. Oren, "Web-based Envoronments (WBLE): Current Pedagogical and Technological State," *International Journal of Research in Computers in Education*, 1999.

[19] M. Donovan and S. Macklin, "One Size Doesn't Fit All: Designing Scaleable, Client-Centered Support for Technology in Teaching," presented at CAUSE98: The Networked Academy, An EDUCAUSE Conference on Information Technology in Higher Education, Seattle, Washington, 1998.

[20] S. C. Bronack and R. E. Riedl, "Distributed Learning Environments: Pedagogy, implementation, and the early adopter," presented at ED-MEDIA, Freiburg, Germany., 1998.

[21] M. Quentin-Baxter, "Hypermedia learning environments limit access to information," , Australia, 1998.

[22] N. Hara and R. Kling, "Students; Frustration with a Web-Based Distance Education Course," *First Monday*, vol. 4, 1999.

[23] M. Stelzer and I. Vogelzangs, "Isolation and Motivation in Online and Distance Learning Courses," , vol. 2000, 1994.

[24] M. Wild and A. Omari, "Developing educational content for the Web: Issues and ideas," presented at AusWeb96 The Second Australian Worl-Wide Web Conference, 1996.

[25] A. Oren, R. Nachmias, D. Mioduser, and O. Lahav, "Learnet - A Model for Virtual Learning Communities in the World Wide Web," *International Journal Educational Telecommunications*, 1998.

[26] P. Brusilovsky, "Adaptive Educational Systems on the World-Wide-Web: A Review of Available Technologies," , 1998.

[27] P. De Bra, "Design Issues in Adaptive Web-site Development," presented at 2nd Workshop on Adaptive Ssytems and User Modelling on the WWW, 1999.

[28] P. De Bra, P. Brusilovsky, and G.-J. Houben, "Adaptive Hypermedia: From Systems to Framework," , 2000.

[29] F. Farance and J. Schoening, "Personal and Performance Information (PAPI) Specification," : IEEE, 1997.

[30] W. S. University, "Comparison of Features, Specifications, Support and Pricing," , vol. 2000, 2000.

[31] C. f. I. T. Marshall University, "Comparison of Online Course Delivery Software Products," , vol. 2000: Center for Instructional Technology, Marshal University.

[32] E. Blackhurst and R. Hales, "Using an Education Server Software System to Deliver Special Education Coursework via the World Wide Web," , vol. 2000: University of Kentucky Assistive Technology (UKAT) Project, Department of Special Education and Rehabilitation Counseling, University of Kentucky, 1997.

[33] K. C. Wright, "The TopClass Experience in Distance Education," University of North Carolina - Department of Libary and Information Studies 1998.

[34] D. W. Thornton, "Using Distributed Technology for Teaching Distributed Systems," in *Computer Science Department*. Dublin: Trinity College, 1999, pp. 100.

[35] G. Meisner and H. Hoffman, "Technology Tools, a Web-based Learning Environment for the Science and Mathematics Classroom," *International Journal of Modern Physics*, vol. 8, pp. 41-47, 1996.

[36] W3C, "Mathematical Markup Language (MathML)," , vol. 2000: W3C, 1998.

[37] D. Ragget and D. Batsalle, "Adding math to Web pages with EzMath," , Australia, 1998.

[38] M. Mark and J. Greer, "Evaluating Methodologies for Intelligent Tutoring Systems," .