# Adaptive Learning Environments for CS Education – From AMLE to Live Spaces


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## Abstract

The move to online learning environment for the global delivery of Australian CS programs has heightened the need for adaptive interactive learning environments. Research has indicated that adaptive and interactive online CS learning environments play a useful role in the provision of lifelong learning but these needs are not being fully met by current tools or COTS systems. This paper builds on a previous implementation of an adaptive multimedia learning environment, (AMLE), a networked multimedia learning environment which attempts to provide the functionality of a traditional intelligent tutoring system and looks at the support of CS learning by the provision of new highly-integrated and context aware tools..



*Keywords*: Computer Science Education, Life-long Learning, Adaptive Context- Aware Learning Environments


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## 1 Introduction

In work published five year ago (Slay 1998) the following questions about online learning was asked. "How can we provide an effective learning environment? We face the pressures of reduced human and financial resources and the demand for quality teaching. Can we justify the time taken to learn a new medium? What are the benefits for ourselves and our students?".

We suggested that a key factor involved in designing an effective learning environment was the use of a graduate quality framework around which to design content, assessment and other elements of technical and pedagogical interactivity. We also pointed out that it is possible to be so entangled with the technology that underpins “delivery” that we fail to pay proper attention to our students’ learning.

## 2 Development of Graduate Qualities within an Implementation of an Adaptive Multimedia Learning Environment

Various researchers who have experimented with adaptive teaching on the World Wide Web (WWW) have used techniques and principles derived from Intelligent Tutoring Systems (ITS) and particularly Anderson’s rule based cognitive modelling (Anderson 1983). Others have used Adaptive Navigation Support to provide adaptive navigation through hypertext pages and thus developed adaptive textbooks for the tutoring, particularly, of software applications (Brusilovsky 2000) .

An ITS is traditionally formed of two parts, an expert system and a communication module. Within the expert system, there are three modules, the student module, the pedagogical module and the domain knowledge module. The student module gives the student history; the pedagogical or course model, provides information about the teaching process, and the domain knowledge module provides the material that is being taught. While proving useful, adaptive teaching on the WWW has not yet been able to supply the full functionality of traditional ITS.

Adaptive Hypermedia (AH) with its strong links to the ITS field, utilise fine-grained hypermedia educational modules with associative links to others. The further coupling of student and course profiles, have resulted in AH learning environments that provide the foundations of student centred work places.

AH systems typically present content in fine-grained modules to enable the real-time allocation of learning artefacts to the learner and enable reusability. The content can be structured or aggregated in different combinations to satisfy the requirements of the lecturer; alternately, the associative links within the network of modules can drive the access. superimposed link annotations provide the learner with relevant information about the modules based on what the system perceives the learner is ready for.

With the movement of courses to an on-line mode, there is a need to develop and enhance the learning environment with a range of features that stimulate the complete learning experience. We have developed a prototype for a Learning Environment (LE) for the presentation of multimedia courses that display adaptive characteristics; the environment has thus been called an Adaptive Multimedia Learning Environment (AMLE) (Kurzel 2002).

The first premise upon which AMLE was based was that the interface should reflect the multimedia artefacts that the students could design and create. Multimedia objects within learning environments, provide a possible enhancement to the presentation of our on-line materials. Ricketts (Ricketts, Wolfe et al. 2000) describes the successful use of a hybrid CD/WWW presentation of course materials delivered in distributed mode where multimedia elements were provided on CD. The Herringtons (Herrington and Oliver 1999) describe the benefits of multimedia within authentic assessment used in a teacher pre-service course. Looi et al (Looi and Ang 2000) describe a collaborative WWW based system that provides for on-line communication and collaboration in the creation of multimedia artefacts for the WWW.

Jonassen et al. (Jonassen, Peck et al. 1999) take the position that the true worth of multimedia and hypermedia might be obtained through the learner constructing knowledge via the use technology, rather than as a mode of delivery. Although there is agreement that the creation of multimedia and hypermedia artefacts is a powerful mechanism for individual learning, the learning benefits attributed to the construction of different media views of content cannot be discounted; dual coding theory supports this assertion and recent experiments (Alty 2002) indicate the significance of media in the presentation process.

Within the functionality of this LE, course designers need to be able to apply and embed with in the delivery system, a quantitative metric for each the Graduate Qualities (GQ) (UNISA) that are seen as the desired outcomes. We propose that the most efficient method for this measure is to base the GQ metrics on the assessment that is performed within the course. These GQs are outlined in the following:

- the ability to operate with and upon a body of knowledge of sufficient depth to begin professional practice.
- preparation for lifelong learning in pursuit of ongoing personal development and excellence in their professional practice.
- effective problem solvers, capable of applying logical, critical and creative thinking to a range of problems.
- commitment to ethical action and social responsibility as a professional and a citizen.
- the ability to work autonomously and collaboratively.
- effective communication skills.
- demonstration of an international perspective as a professional and as a citizen.

We utilise two forms of assessment; namely formative assessment that includes the mastery (or competency) of particular concepts or skills conducted generally at a weekly level, and summative assessment that necessitates the use a range of knowledge/skills in its satisfactory completion. These range from producing a range creative multimedia pieces with associated documentation, to investigating and writing reports on particular topics of interest.

For each assessment piece, whether it be at the concept or assignment level, we store within the course model and make available to the student, a percentage representation of the GQ as an outcome of the assessment activity. Knowing the relative worth of each assessment piece then, provides us with the data to audit any course format on the system and provide further information about the course's effectiveness. We also acknowledge that the GQ outcomes will be closely tied to the instructional methodology chosen by the lecturer. To accommodate this, the summative assessment pieces are delivered dynamically over the Web.

## 2.1 AMLE's Architechture

AMLE provides multiple access to course materials for students along with course management materials for staff over the Internet. The student (or client) works with course materials through an application that interacts with a remote server. It also accesses locally stored documents files. A number of players are provided on the client side which are activated as a result of student and domain model data distributed by the server. Staff/tutors interact with the course and student model through a WWW browser. Media files expensive in terms of delivery time, are stored locally but administered over the WWW.

## 2.2 Interface details

The main interface provided for students to access the learning materials can be classified as a hybrid browser. It takes advantage of the multimedia development environment and enables a range of concepts players used.

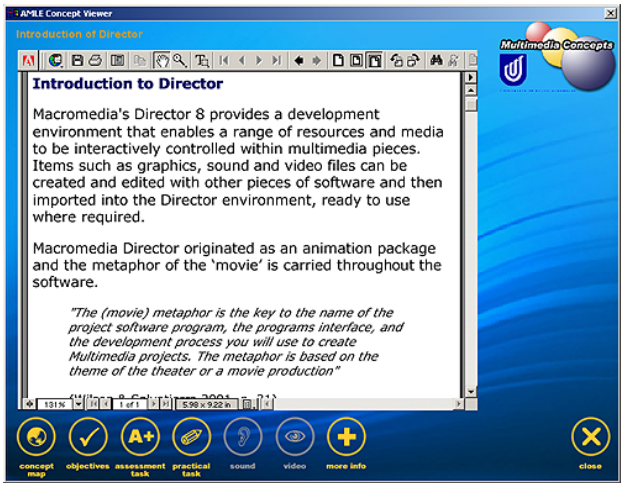


**Figure 1. The Default Concept Viewer**

These range from a concept being displayed as text formatted with HTML tags, to a concept displayed as an Acrobat pdf, containing both textual and graphical information (see figure 1). Video and audio formats can be utilised, along with appropriate animations.

Once registered after an authentication process, the user is provided with the current session, or the pre-test for that session if this is the first time in. From there, individual concepts can be accessed. The default player is one that displays the content in pdf format. This was chosen so that the format of the content (images and text) could be guaranteed while still providing web facilities for hypertext links in the documents.

## 2.3 Domain knowledge

Our course model is organised hierarchically into courses, sessions, concepts and documents. Sessions have been defined from concepts; sessions can have any number of concepts but one concept appears once within any session of a course. A concept consists of many documents and data stored on the server; a document can be the content of a concept, its objective, any pre-requisites, and assessment criteria. There is a player associated with each document format; the player displays the information in an appropriate manner. These players are generally located with the client. Each document can exist in multiple media formats that include text, video, audio, HTML files, and Acrobat pdf files.

The implementation is supportive of other possible domains of knowledge; the delivery system then is content independent. The course metadata is stored on a remote server along with the student profile information. Existing management tools allow for the easy creation of course structures, course lists, and the registering of assessment results. The content is organised as a number of concepts and/or skills that need to be satisfied. Currently we organise this content into sessions that correspond to associated groups of concepts (a week's worth of work).


**Figure 2. The Session Viewer**

To accommodate a range of students at various levels in their programs, we pre-test at the session level. For the practical components, students might be able to demonstrate the possession of some particular skills; this then needs to be handled manually and/or electronically.

The concepts/skills that we discern the student to have competence in, are highlighted by the system but still available to the student if they wish to access the materials for revision purposes.

The dynamic components of the delivery system involving the course structure and assessment pieces, student profiles and assessment results, episodic data mapping student usage, and data of those on-line, is stored at the server side. This 'dynamic' data allows the system to indicate to the users, information about the concepts/tasks that they have covered. It also provides them with a current 'report' of results of assessment pieces.

Other tools that are used that might be used in the learning process eg email, chat facilities, submission mechanisms, glossary, course maps, search engine, book marking, etc. along with more general facilities like audio players, notepad etc. are provided. As students become more familiar with the environment, the instructional strategies may vary.

## 2.4 Student administration

An on-line instructional management system has been constructed to establish courses based on concepts and sessions. An 'Administration Tool' enables lecturers and tutors access to our student model. Lecturers can add/delete a tutorial group, add a new student, search for existing student, and update student's detail such as practical scores, assignment scores and exam scores.

Tutors have access to update and search facilities of students' practical and assignment details. AMLE uses and maintains student profiles that contain a summary of the student's past experiences and other preference information. The course model and student profile allows students to proceed at their own rate through the learning environment with this access being influenced by a student's competencies and preferences (i.e. the student history of the traditional ITS).

The management system enables tutors to enter marks electronically and subsequently manage the assessment components of the course. Reporting mechanisms then cope with student, tutor and course co-ordinator requirements.

# 3 Discussion of Graduate Qualities in AMLE

The body of knowledge is presented to the student in AMLE as a sequence of concepts that can be either declarative or procedural, grouped into sessions based on the expert's view. Mullier inserted tutorials into the semantic network making up Hypernet (Mullier and Dixon 2000) to provide the students with tutorial tasks to reinforce learning. AMLE embeds practical sessions within the course model to reinforce the procedural content.

Constructivist principles underpin the environment and students can actively involve themselves, creating items and placing them into their workspace or on the WWW, searching out content and skills, and satisfying authentic tasks.

As students become familiar with the both the course and the LE, a range of tools allow both the students in their individual learning endeavours, and lecturers in their instructional methodologies, to break away from the prescribed expert view. Together, they provide the macro level scaffolding (Bannan-Ritland, Dabbagh et al. 2001) that allow the students and lecturers to use particular content in different, albeit overlapping, contexts

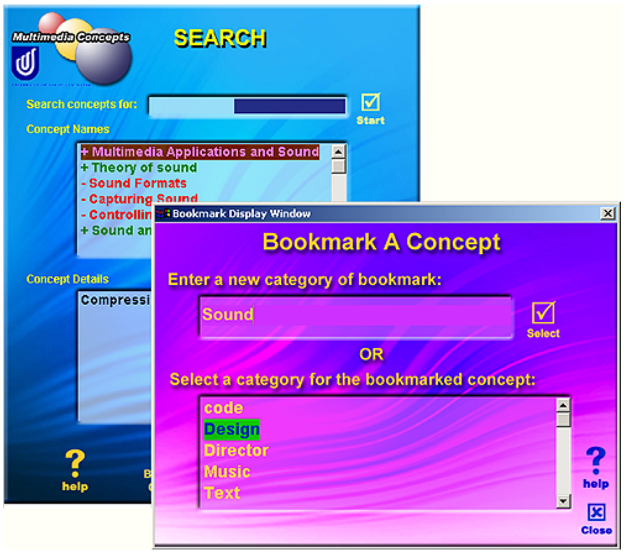


**Figure 3. Searching and bookmarking**

We might choose to structure our course for example, as a series of investigations. One of those investigations might be entitled Sound in Multimedia; the practical task within this investigation could be to design and create and MP3 player.

Possible areas to be addressed could include:

- the possible application of sound in multimedia applications;
- theory of sound - representation, capturing characteristics etc;
- sound formats - compression, filetypes, size etc.
- sound capture;
- sound control within multimedia applications;
- ethical considerations re: copyright etc.

Life long learning along with problem solving skills are being facilitated in these investigations; the search space is not restricted to the network of concepts but is inclusive of the WWW because of the hypermedia environment that it is couched in. By its very nature, the LE is inclusive of an international perspective.

Problem Solving skills are continually being addressed through the practical nature of the domain. Students are continually challenged with practical tasks to satisfy. Ethical and international issues can be discussed where appropriate e.g. the distribution of MP3 audio files.

Communication facilities involve student/student and lecturer/tutor/student interactions via online discussion groups that support collaborative and/or group learning. These could be practical discussion groups with a number of their peers currently logged on addressing some weekly task. Alternatively, they might be one on one interactions with the tutor or lecturer.

The system supports on-line collaboration within groups and enhances the communications that a small group of online participants could be involved in; further, assessable activities could be employed that specifically require group interactions/work.

While we have had no long term educational evaluation of the pedagogical effectiveness of AMLE, which has been a test bed for the evaluation of our own, and others' concepts of teaching and learning, we have begun to question the lack of interactivity and adapability/adaptivity (Oppermann 1997) in our own environment and have been challenged to explore other metaphors and concepts for online learning in CS. We examine the term "live spaces".

## 4 Designing Educational Live Spaces on the Web

The live in live spaces reflects the fact that the environment is dynamic (or alive) in that it changes depending on its context of use, is driven by adaptive workflow mechanisms and uses new forms of adaptive media. Space reflects the notion of through-wall environments that allow participation from individuals in other locations (or spaces) by way of virtual avatars, mobile computing and extended video conferencing. Live spaces are also an extension of workspaces, a concept that has been around for a considerable time.

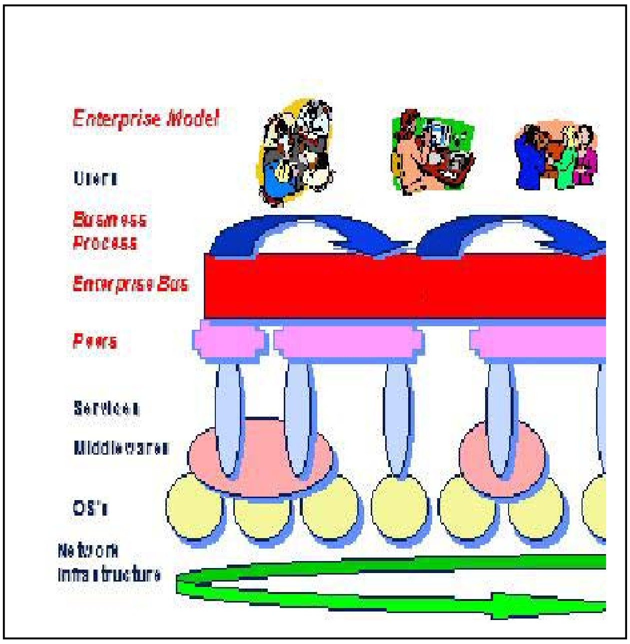


**Figure 4. Enterprise Systems Architecture**

The fundamental requirement is that a system has to be able to handle a range of different situations in certain contexts to be able to develop the GQs that we desire in our learners. It has also become increasingly unacceptable for users to have to adapt to systems instead of systems adapting to their needs. Life-long learners, often highly qualified IT professionals, are demanding to have the necessary system capabilities accessible when and where they need them. Their teachers want to provide the adaptive and interactive content which modern CS pedagogical research is indicating.

In a CS teaching context, this means that the tools, rendering mechanism and sources of support material must be adapted to the subject (e.g. AI, C++ programming, SQL) being studied. Many students are active professionals and their learning needs vary from day to day and project to project

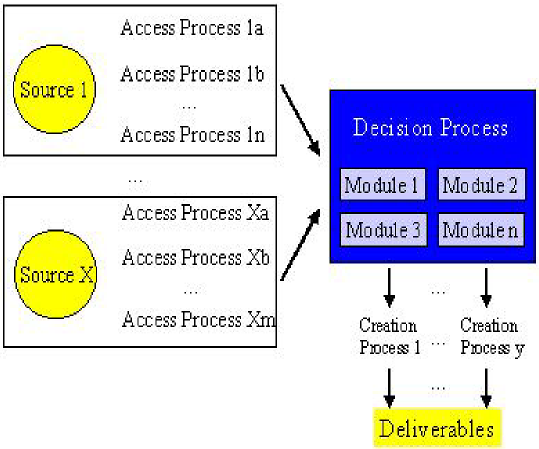


**Figure 5. Basic Components of an Educational Live Space**

Business processes are served by the underlying IT infrastructure via the Elvin enterprise bus, which allows services to be connected via standard interfaces. This model, which works well for enterprise models, can also serve as the basis for creating educational live spaces.

The major components of an educational live space could be grouped into sources, supplying the student history, teaching process and teaching content with attached access processes, decision processes and deliverable creation processes, with decision processes being only partly automated. Processes attached to the sources guarantee that the support environment is active (depending on the situation reactive or proactive) rather than waiting for the user to push it into action.

This model of an educational live space leads to a framework for setting up context aware CS learning environments, which are able to respond to specific needs of users.

To guarantee high usability and flexibility, the best technology choice for setting up a context aware work environment today is the Web. Access and rendering can be assured for a wide variety of devices, ranging from mobile phones and handheld systems to powerful server and desktop environments. Depending on the end-user equipment display capabilities might be limited, but assuming that an advanced handheld or laptop computer will be the standard, live spaces can be considered a realistic perspective. Presuming that most information is text based, rendering power need not be excessive. Consequently, the computational power can to a large extent be concentrated in the server infrastructure feeding the system, where it will be needed for running highly complex search, scheduling and reasoning algorithms. The end-user device will, due to this high computational complexity have to be limited to the role of an I/O client with little local intelligence, but it needs a reasonable display. With most of the system intelligence being concentrated on the server, high bandwidth and stable communications become essential.

To meet the end-user demands, the server infrastructure will have to be highly configurable and will have to rely on advanced middleware, of which workflow management systems are a major component.

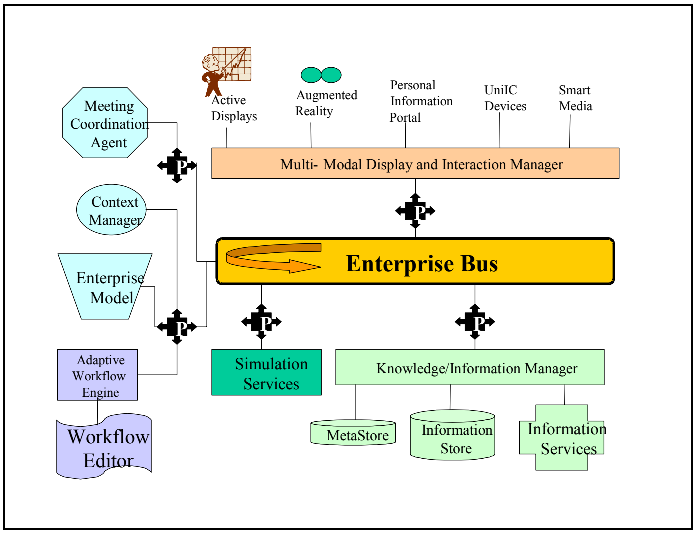


**Figure 6. ACAWE Reference Architecture**

As this middleware is itself only a component that has to be able to communicate with other building blocks of the system, the idea of grouping the whole infrastructure around the Elvin bus (Vernik Quirchmayr et al. 2001), can be used as starting point for a highly flexible solution.

This architecture, with system components communicating via an enterprise bus, is highly flexible and allows the concentration of computationally intensive tasks, such as searching, scheduling, and simulation on the servers. Limiting the client to display functionality gives the possibility to use a wide range of equipment, starting from advanced mobile phones. The only remaining restriction is the quality of the display, which in reality means that handheld computers currently are the lower boundary. For educational applications the highest workload will be on the workflow system, the knowledge and the information manager. Being able to flexibly plug in different information, knowledge management, and workflow management systems is the biggest strength of this approach. With the web becoming accessible from different types of widely spread devices, it is the obvious rendering platform for results delivered by the support environment. Access comes at a reasonable cost and can be considered as quasi-ubiquitous.

## 5 Conclusion

The aim of the paper was to show how adaptive teaching does produce qualities in our graduates that will equip them for industry and begin to produce lifelong learners. We do believe however that context aware work environments could contribute to improving learning environments for computer science professionals and suggest a way towards adapting and implementing the approach relying on a Web-based delivery. With technological infrastructures becoming highly flexible due to recent developments, mainly enterprise buses, and improved web access, the time seems to be right for an attempt towards designing a new generation of computer science learning environments.

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