

# The learning computer: a low bandwidth tool for bridging the digital divide in distance education

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## Abstract

*This paper reports on the successful prototyping and evaluation of a low bandwidth, easy-to-use tool for distance learning. IMMEDIATE (Integrating MultiMedia in a DistAnce learning and TEaching environment), addresses the digital divide in education through a learning computer that provides a specialised e-learning environment for the PC, which is more-widely accessible and more usable to students than web-based Learning Management Systems (LMS) and works with or without an internet connection. Because the learning computer does not require the speed and multifarious functionality of today's desktop computer, it will potentially run on cheaper special-purpose hardware, recycled older computers, or ubiquitous devices which plug into any computer, to support "anybody, anywhere, anytime" e-learning.*

## 1. Motivation for the project

Ideally, as computers pervade all aspects of our lives we should become less and less aware of them. They should be so seamlessly embedded into our living and working environment that we take advantage of them without being conscious of their presence. From this perspective, computerisation supports and empowers humans in our endeavours rather than displacing and marginalising us. Humans remain at the centre of a more productive society.

Over the past decade, mechanisation has had a major impact upon distance learning, with computer-based courses delivered over the World-wide Web increasingly replacing traditional correspondence courses. As rapid advances in computer and communication technology make possible real-time video-conferencing and virtual classrooms via the PC,

some even question the future of “bricks-and-mortar” learning institutions. In fact, what has become known as e-learning is more and more promoted as the future of education. With the opening of the new millennium, it was said, the communication potential of internet-linked computers was turning the world into a global village.

However, the sobering reality is that the great majority of humanity remains in an “e-wilderness”. As recently as 2002, one communication studies researcher observed that online information services such as e-learning were still focussed upon a few hundred “wired cities”, while ninety-seven percent of the world’s population had no Internet access and almost two-thirds of households had no telephone, let alone the broadband delivery and multimedia computer required for virtual classrooms [1]. In 2004, in acknowledgement that the digital divide between people who have access to and know how to use technology and those who do not is a growing problem in developed and developing countries alike, Microsoft announced that it would spend tens of millions of dollars on community-based technology learning centres around the world .

The starting point for the learning computer project was anecdotal evidence and personal observation that there are major technical and usability obstacles impeding the delivery of distance education programmes for individual home study via web-based LMS especially in rural communities in the developed and developing countries. We were concerned that e-learning, rather than offering new opportunities to narrow the divide between the world’s haves and have-nots, may actually be perpetuating and even widening educational inequalities through introducing a two-tier system based on access to, and ability to use,

sophisticated computer and communication technology.

These concerns initiated a search for ways in which computer technology could be applied to distance learning so as to offer students a learning advantage over correspondence-based courses, without incurring a disadvantage in terms of accessibility and usability. Our research was broken into three main phases, investigating the problem, conceptualising a solution, and testing this conceptualisation through prototyping and evaluation with users.

## 2. Investigating the problem

An extensive review of conference papers, journal articles, books, web sites, industry publications and news reports was conducted. The main results have been published previously [2] and are only briefly summarised here.

“Distance learning” covers a broad range of scenarios with very different requirements – from specialised in-house job training, through radio schools for primary children, to open university adult education courses. It was therefore necessary to clearly focus on a specific sector: the provision of university-level, home study programmes for students unable to attend normal lectures.

Computer systems, through their ability to rapidly store, manipulate and communicate multimedia information, have the *potential* to provide multi-dimensional distance learning *environments*, which incorporate passive (teacher-centred) or active (student-centred) learning styles, group or individual work, interaction, and simulation. However, such environments have not been fully realised for university-level distance education. Existing LMS have tended to emphasise the authoring and course management needs of the education provider rather than the usability and accessibility requirements of the student. Learning Content Management Systems (LCMS) are more geared towards teaching specialised skills than broad-brush university courses. And adaptive tutoring systems have proven too complex to implement to come into general use. Moreover, e-learning systems often assume levels of computer literacy and access to high-speed technology more in line with the resources of public or private institutions than with students studying at home or in developing countries.

Attempts to replace teacher and textbook altogether and create entirely electronic virtual institutions have not been successful at the university level.

From this review guidelines were synthesised for

developing effective university-level e-learning systems for home study. E-learning should provide a student-centred, holistic learning environment which extends the university community to the distance student. All key features should be evaluated for functionality, usability and accessibility in the worst-case scenarios like that faced by students in by students in developing countries and more isolated rural communities.

## 3. Conceptualisation and specification of a learning computer

E-learning systems, either LMS or LCMS, are typically server-centred, delivering lessons to the student via a general purpose web browser. Efforts to enhance the student's learning environment have emphasised providing more individual adaptivity, within that framework. However, some research results suggested to us that our objectives of maximising the learning functionality available to the distance student while minimising the usability and accessibility problems of web-browser-based systems, could be better met through more user-centred strategies of specialisation [3] [4], customisation [5], and localisation [6].

By considering these strategies together, the concept crystallised of a *learning computer* – a special-purpose computational device which integrates all the features a student needs for learning into a simplified, specialised, individualised, networked user interface. The learning computer provides alternative study modes, defined by a set of elements, each of which corresponds to a basic constituent of university study. Learning by lecture, for example, may involve a presentation by the lecturer, a set of slides provided by the lecturer, and notes made by the individual student. Learning by tutorial, on the other hand, may involve a one-to-one interaction with a tutor as well as notes made by the individual student.

Having visualised the new system in this way, it was then necessary to specify a prototype in more detail. The key decisions made at this stage were:

- That the learning computer would be implemented as the client in a client/server network in which most functionality is distributed to the client side. Communications and learning content would be updated by periodically linking to a central repository of messages and learning resources via the Internet, satellite, or the post (i.e. CDs), rather than as a browser client downloading pages from a web server. Updates could then proceed in the background while the learning computer is in use.

- That the student interface would be implemented on the Windows platform as a specialised direct manipulation graphical Learning Shell replacing the operating system GUI, rather than by adding functionality to a general-purpose web browser. This Shell would provide "just-enough" of the underlying Windows functionality "just-in-time" to support the required learning task. It would be assembled on a modular basis using an object-oriented rapid application development environment which supported reusable software components. Delphi was chosen for this.

- That navigation and other user interactions with the Shell would be simplified by managing them through an intermediate system layer between the interface and the operating system, which models the modular, hierarchical structure of an extramural course and maps the user's learning tasks to the appropriate computer operations. This layer would also model the student sufficiently to provide the reference point for individualising the Shell to a specific user.

- That learning assistance would be provided to the student through an integrated system of electronic mail, collaborative work groups and online help built around a replicated SQL-compliant database. The online help system would be queried by the student via a user-friendly interface to obtain more information on an issue, or guidance on where to find more information. In this way, the learner obtains assistance through discussion with other students, contacting the course tutor, or by directly querying the database. Student queries and their outcomes could be logged as a means of dynamically improving the support system.

To implement these decisions and evaluate the overall concept, a course authoring and management application and a communications management component needed to be built and integrated with the learning computer into a network. This overall system we have called IMMEDIATE.

#### **4. Evaluation through prototyping and user testing**

Incremental prototyping was used to evaluate and refine the main elements of the design specification and then to get the IMMEDIATE network operational.

The Learning Shell user interface has been assembled in Delphi from reusable "drag and drop" software components. Each of these encapsulates a particular learning element such as a student notebook or a lecture presentation. This components-based architecture provides a robust, modular structure capable of incorporating more advanced technologies

as appropriate.

As a network user interface in an internet-based client/server network, the Learning Shell has some functional and architectural similarities to a modern platform-specific web browser like Microsoft's Internet Explorer which is tightly linked to the underlying operating system. It is built around a Controller unit that provides an API through which interface components interact with each other and with the reference model layer. The model layer is a set of data structures and related operations, each of which models a different aspect of the learning computer and its current state.

The Controller plays an analogous role to a web browser's controller, which manages the other browser components and calls on them to perform operations specified by the user. The learning component may display a file stored on the user's machine, it may link seamlessly to remote resources and applications via a network, or it may execute another (hidden) application installed on the student's computer. However, the Learning Shell Controller, through reference to the model layer, has additional capacities for managing the interface to simplify and minimise housekeeping tasks and free the user for learning. In tandem with the learning components architecture it provides a direct manipulation interface which seamlessly integrates all necessary functionality into a single, simplified, adaptable framework.

The learning support system is built upon a database of definitions, elaborations, references and URLs linked to keywords associated with each topic in a course. To get help with a concept, the learner interacts with the system by selecting from a list of simple English questions, by responding via dialogue buttons, or by selecting from a Concept Map displaying related terms. Algorithms translate these interactions into SQL queries, prioritise the order that results are displayed, and assess their usefulness to the learner. Group discussion and tutor queries are also organised by topic and may be used by the tutor to expand and update the database.

The IMMEDIATE network (Figure 1) uses an FTP server as its gateway, controlling access to the Course Repository. Because most functionality resides at the student end network traffic is light. Updating the learning computer consists of transferring data or system files via FTP or from CD or DVD. To support a communications model based on a replicated database, each user's view of the database is copied to that user's machine from a central master copy. All updates are SQL result sets which are transferred as plain text files using custom protocols.

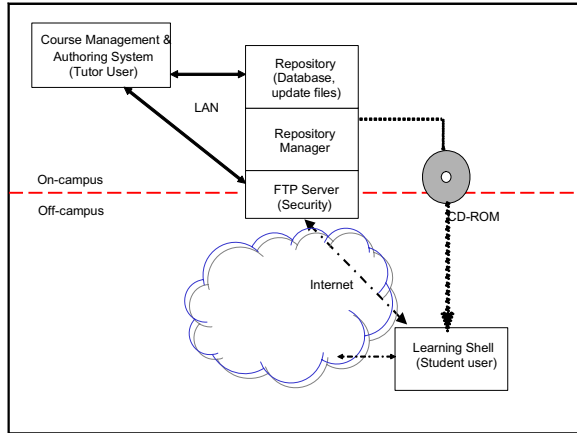


Figure 1. IMMEDIATE network components.

The final incremental prototyping step was to get IMMEDIATE up and running over a LAN to ensure that its component applications would correctly work together to support the required functionality. IMMEDIATE was then installed to run over the rural telephone network and tested with four volunteer users from a remote farming and fishing community over a period of two days. The goals of this evaluation were to determine that IMMEDIATE performed reliably under these conditions and that all the learning computer's functionality was accessible to the user, and to assess the usability of the Learning Shell.

Overall the volunteers embraced the learning computer as an easier and more effective vehicle for achieving tasks related to e-learning. Some of the points they singled out were: simplicity, ease of use, integration, speed, timeliness, relevance, robustness, friendliness, transparency, consistency, and clear instructions.

Many of the interviewees' comments alluded to the difficulties they faced using their computers at home. Their comments strongly supported the argument that personal computing systems have become too complex for learning, and that poor rural internet service renders server-centred LMS unworkable.

The evaluation is discussed more fully in [7].

## 5. Conclusion and discussion

The main outcome of this project has been to develop a learning computer through which it is possible to combine the benefits and power of standalone computing with the collaborative potential of the network, in an easy-to-use distance learning environment. Through its ease of use and integrated functionality the learning computer offers advantages for all distance students. Moreover, through its ability

to provide e-learning access to students in remote locations beyond the reach of web-server-based systems it offers a realistic path towards bridging the digital divide in university-level distance education.

The *learning computer* is distinct from either a LMS or a LCMS in several important respects. First, the learning computer goes much further than LMS and LCMS have been able towards delivering distance education on an anybody, anywhere, anytime basis. All the collaborative and communication functionality of the learning computer, including group work and learning support, is implemented using an asynchronous model and a replicated database that can be accessed and used anytime, regardless of whether a network connection is currently available.

Second, distance students themselves, rather than the education providers, are the primary target users. An integrated, holistic approach is taken to e-learning, in which the usability of the student's overall computing environment is considered as important to successful learning outcomes as the learning content itself.

Third, the learning computer builds upon the ubiquitous computing approach to e-learning [3], [4]. The computer is embedded in the learning environment in the form of a specialised graphical user shell. The object is to make the computer vanish for the learner by taking into account the total environment (hardware, software and human factors).

The simplicity of IMMEDIATE is based upon modelling the forms in which learning will be delivered, while leaving most content to be authored separately or picked up from reusable learning repositories. Learning components differ from software components (controls) in that they encapsulate a single domain task rather than a single software task. They differ from reusable learning objects in that they implement the form of delivery rather than the content of a learning module. The learning components are the centrepiece of a modular construction which supports reuse on three levels – the student (multiple courses), the teacher (reusable learning materials), and the software engineer (reusable code).

## 6. Ongoing Work

Research is proceeding along two axes: evaluating IMMEDIATE in an actual distance learning course, and re-engineering the prototype to support mobile learning and low-cost hardware.

Preparations have begun to trial the learning computer in a first year language course at Massey

University in 2006, where it will be offered as a delivery option to distance students. A particular focus will be on evaluating the effectiveness of the online help and search facilities.

IMMEDIATE implements the learning computer as a Windows application on a specific computer. Its "anybody, anywhere, anytime" goal would be better met if students did not need to buy or borrow their own PC or notebook and could use any available computer. To this end, we are customising the Learning Shell so it can be installed on and run from a plug-in flash-memory device as a *mobile* learning computer.

A Linux-based implementation carries a greater programming overhead while offering a cleaner approach, because the specialised user shell can be built directly on top of the Linux kernel. We are also exploring the feasibility of implementing a Linux version along two lines:

- As a low-cost single-purpose computer. Because it works with lower end technology, the learning computer could be built from cheaper components or recycled older PCs, and distributed to students.
- As a self-booting portable device which can be plugged into any PC to temporarily convert it into a specialised learning computer. This offers a way for a learner to take full advantage of the learning computer approach, while sharing a computer with other household members and other tasks, or while studying from different locations.

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