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Computer systems for distributed and distance learning

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Abstract Network-based learning is now such an important area that it would seem timely to examine progress to date and to draw conclusions regarding the direction of further research. This paper is the result of a survey of computer systems for distributed and distance learning, focusing on projects that help to illustrate the evolution of this important field. An examination such as this is important in its own right as a resource for other researchers wishing to pursue the subject further, but the survey also helps to highlight some of the major trends of past projects and to suggest some of the ways in which progress may be made in the future.

Keywords: Campus; Communication; Distance; Groupware; Mediated; Review; Tutorial

Introduction

The vast increase in access to computers over the past two decades has led to a corresponding growth in the production of software designed for educational purposes. One of the many advantages to be offered by such packages over more static means of presentation such as textbooks is increased interactivity. In particular, automated feedback can do much to guide learning and to correct mental models when misinterpretations of material occur (Barker, 1994). However, as a number of critics have pointed out:

> 'Stand-alone media-based packages will never be sufficient, because none of the media can adequately support the discursive activities that are essential for academic learning. . . Given that academic knowledge is a consensual description of experience, it follows that discussion between teachers and students should play a very important part.'
> (Laurillard, 1993)

In light of this, an alternative tack has been to research into ways of using computer programs not as replacements for human tutors, but rather as support tools for aiding the teaching process. A wide and varied range of areas in which computers and software can play such a supporting role have been identified, especially in the higher education sector and for on-site

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training in the workplace (Chesmond & Tucker, 1990; Gardner & Darby, 1990; Goodyear & Steeples, 1992; Leiblum, 1992). Included among these are: creation of material for on-line courses (Ellerman *et al*., 1992); courseware authoring systems (Jackson & Bell, 1992); interactive course delivery (Newman, 1993); electronic books (Benest, 1990); automatic submission of work (Luck & Joy, 1995); and automatic assessment and grading (Jackson, 1996; Jackson & Usher, 1997).

In the context of computing support for education, a development that has had far-reaching impact has been the increase in computer connectivity. Schools and colleges now almost universally link their computers into local area and even campus-wide networks, and hooking up to the Internet has never been easier or cheaper. With the current trend being to teach ever-larger numbers of students without corresponding increases in human resources, it comes as no surprise that many researchers have devoted their efforts to exploiting the educational potential of computer networks.

This paper surveys the progress in the use of computer support for network-based learning. The focus is not on any organisational, managerial or financial considerations, but on computer software and hardware solutions that have been proposed and implemented. A comprehensive survey, detailing every such system, would be an impossible task; instead, a more reasonable number of important projects have been selected and they illustrate the evolution of the research area.

Within this evolution, it is impossible to overstate the impact that the World Wide Web has had on making networked computers more accessible to educators and learners alike. As a medium for making course material available and for structuring and presenting information connected with such courses, the Web is unsurpassed when considered in terms of the sheer numbers who make use of it in this way. It is for this reason that the survey that follows is partitioned into Web-based and non-Web-based systems.

Within each of these two categories, a distinction was made between distributed systems and distance learning systems. This secondary classification is admittedly less clear-cut, since distance learning systems tend to be distributed, and there are many properties common to both camps. However, the literature suggests that distance learners have their own particular needs requiring research tailored to their situation. Traditionally, students undertaking distance education courses have been at a disadvantage in comparison to those attending an institution, in that communication with their tutors and peers has been severely limited. One of the promises of increased access to networked computing technology is that the physical barrier of distance need no longer be an obstacle to interactive tuition. The ongoing advancement of computer-based communication technology has presented practitioners in the field with new possibilities for overcoming the 'one-way' nature of distance learning. The many benefits to be obtained include the potential for bringing together individuals on opposite sides of the globe to work on group projects, and a reduction in the costs and effort associated with distributing and maintaining course materials (Shor, 1988).

This paper is intended as more than just a survey of systems. It aims to help those wishing to pursue research in the area and serves as a means of identifying weaknesses in existing research.

Distributed and distance learning systems

Non-Web Systems

Distributed Systems The use of networked computers for educational purposes only became practical with the advent of low-cost personal machines. As such, projects making use of distributed computing began to appear around 1980. One of the earliest examples was the *SOLO/NET/works* project (Dwyer & Critchfield, 1982), notable for its focus on 'inventive learning', in which students are encouraged to adapt, amend and possibly extend the knowledge of others in their solving of problems. This was achieved through support for role-playing simulations in which each student had a terminal in the network running a local process relating to the role which the student was fulfilling in the simulation. The complete simulation environment was controlled by a 'distinguished process' on a separate machine. An example of the type of simulation performed is that of a stock market, with students assuming the roles of brokers, bankers, and so on, the distinguished process controlling the state of the markets and updating data.

A few years later saw the initiation of two of the largest ever CAL projects; these were undertaken by Carnegie-Mellon University (CMU) and the Massachusetts Institute of Technology (MIT). In 1982, the former launched *Andrew*, the aim of which was to provide an environment in which the workload involved in the devel-opment of educational projects could be distributed (Isaacs, 1989). *Andrew* was a campus-wide network system linking workstations and personal computers, and was developed in the hope that the availability of computing resources would stimulate the adoption of CAL within CMU. Prior to its implementation it was envisaged that *Andrew* would affect education in CMU in four main ways (Morris *et al.*, 1986):

- The use of graphics workstations would stimulate efforts to develop CAL material;
- The creation and use of new tools would aid research in CMU;
- The community's ability to communicate would broaden and deepen;
- Access to centrally stored information would be enhanced.

Given these objectives, a number of applications were created with the aim of supporting such processes. In addition to tools, such as text and figure editors, notable applications included the *Andrew Message System* (AMS) (Borenstein & Thyberg, 1991), featuring a multimedia mail and bulletin board system. This allowed the creation of 'active' messages which could prompt a user for a reply, for example by multiple-choice forms. The project team also identified some of the problems giving rise to staff reluctance to develop courseware; these included lack of patience, time and programming skills. They attempted to alleviate these difficulties by developing an authoring language called *CMU Tutor* (Morris *et al.*, 1986).

At about the same time MIT began *Project Athena*, although this took an entirely different approach to the development of campus-wide CAL. Whilst the essence of *Andrew* was an environment designed to encourage CAL creation, the aim of *Athena* was to encourage CAL projects in the hope that the properties of a suitable catch-all environment would become apparent (Isaacs, 1989). A further difference between the enterprises lay in the projected use of the two systems. Whereas *Andrew* aimed to support all users on a campus – staff, students, administrators and academics — *Athena* most definitely focused on the teaching of undergraduates (and, to an extent, postgraduates), but did not support staff in their research.

When considering the difficulty in assessing the impact *Athena* may have had on teaching practices at MIT, an important observation was that:

> 'Part of this difficulty has resulted from the largely technology-driven frame of reference in which computation has been viewed; universities have often simply accepted the specific technologies of current hardware and software before asking how they might use them.' (Balkovich *et al*., 1985)

It should be noted that this argument can still be levelled at various CAL projects.

In an effort to address this problem the *Athena* developers contemplated the various ways in which computers might be used within an educational environment. They listed five: the conventional use in teaching courses such as computer science and engineering; administrative use; generic use for running applications such as word-processors, spreadsheets and databases; asynchronous communication; and as an integral part of the instructional process. It was on the final use that the team members concentrated, including the use of computers for running simulations, for facilitating course–related interaction, and for presenting material to students.

Using an approach similar to that of *Athena*, but on a much smaller scale and tighter budgetary constraints, was a project undertaken at Stanford University (Isaacs, 1989). Clusters of workstations were made available and a *Faculty Author Development* (FAD) programme promoted the implementation of CAL by offering assistance with equipment, design and programming support (Osgood, 1987). A spin-off project developed courseware tools. At Brown University, meanwhile, another project to computerise the campus was underway (Schipp *et al*., 1983). Early experiences from this were reported after the introduction of a network of workstations for teaching computer science (Van Dam, 1984).

In the United Kingdom, distributed CAL projects took much smaller forms. Most reports considered the use of computer networks within only a single department or to fulfil a specific role — for example, the studies at Kent into Campus Ring networks (Makinson & Moraji, 1988), and the use of conferencing in a Psychology Department at Durham (Crook, 1988). European enterprises fared better. The *COSTOC* project (Maurer, 1987), for example, had as its objective the provision of an extensive database of lessons making use of 'presentation-type' CAL (Maurer & Makedon, 1988). This is one of the oldest forms of CAL, in which information is presented to students in frames containing text, graphics and animations, similar in nature to Apple's *HyperCard* (Apple Computer Inc., 1990). Suggestions concerning navigation can be made by tutors, but the students are relatively free to choose their own path through the frames.

Using *COSTOC*, students could download lessons from the database and view them locally. Although the system also has obvious potential for distance-learning, it has been included here as its original purpose was to support the common campus teaching model using lectures and laboratory classes. Later developments saw the introduction of hypertext to form *HyperCOSTOC* (Huber *et al*., 1989), and a diversification into other subject areas (for example, mathematics (Gillard, 1990)).

Another European project with similar objectives was started around 1990 and was called *COLOS* (Härtel, 1990). It was aimed at supporting teaching at university level by producing *UNIX* and *X-Windows* based interactive learning programs for science, computer science and engineering, much as *Athena* had done a few years earlier. The difference with *COLOS* was that the project members were distributed across Europe in no less than nine countries, each member being responsible for producing support for a particular set of topics. In the first published results of the project it is interesting to note that one of the problems which the project members encountered through their choice of implementation tools and environment was that:

> '…up to 98% of programming effort was used for developing the interface, the graphics output and the control structure, while only the remaining 2% was needed to develop the core of the program relating to the main scientific topic being studied.'

This was precisely one of the problem areas the *Andrew* developers had faced almost 10 years earlier, also within a *UNIX* environment. Where the *Andrew* team had developed an authoring tool, the *COLOS* team members took to using an object-oriented prototyping tool called *RMG*.

Begun in the 1990s, *Project NESTOR* (Networked Systems for TutORing) examined the use of networked multimedia workstations in a computer supported authoring and learning environment. After considering how best to draw on the benefits and address the problems associated with using hypertext and hypermedia for educational purposes, the authors married hypermedia with an object-oriented approach to create hyperinformation (1990b; Muhlhauser, 1990a). Three main goals were identified for this project (Muhlhauser & Schaper, 1992):

- to create a fully functional authoring/learning environment;
- to computerise the instructional design domain with an emphasis on co-operative work and multimedia;
- to facilitate the use of modern computing and network technology.

The system comprised a kernel and a number of generic software tools. For example, those relating to the second of the goals listed above included *GroupIE* for collaborative applications support (Rudebusch, 1991), and other tools associated with synchronisation and handling of multimedia objects (Blakowski *et al*., 1991).

In 1992 in the United Kingdom a project making use of *UNIX* and concentrating on the management, development and automatic assessment of practical exercises, was started (Benford *et al*., 1993). The project system, called *Ceilidh,* was initially targeted at a *C* programming language course for undergraduate students. Using this system, the students could read online copies of their assigned weekly tasks, and then obtain a skeleton program upon which they could build and test their own solutions. They could subsequently submit their solutions electronically, to be assessed either by a human tutor or automatically by the system (Benford *et al*., 1995). A number of sites have made use of *Ceilidh* to develop their own courses, with initial evaluation providing positive feedback (Benford *et al*., 1994). Recent work on the *Ceilidh* project has focused on the conversion of the system to other platforms and on the creation of new course material (Foxley *et al*., 1996).

A European project that was claimed to offer a 'tool for everyone' (Dvorak & Kveton, 1993), *FAMULUS* aimed to support teaching and learning in the areas of numeric computation, simulation and modelling. Similar in some ways to *Andrew* in that it provided an environment in which further applications could be developed, *FAMULUS* featured context-sensitive help, dynamic display of results, and its own programming language (cf. *Andrew's CMU Tutor*).

Distance Learning Systems Typical of much of the research performed in this area are the studies into the use of computer conferencing as a medium for the delivery of material to distance learners, and as a means of facilitating communication among students and their tutors. The UK's Open University, for example, adopted a 'network' approach in supporting distance learners on some of its courses, in order to improve feedback to those students (Jones *et al*., 1992). A policy was implemented whereby students were required to arrange access to equipment meeting the university's specification. When computer conferencing was introduced, studies were performed to assess its benefits. Those who made use of the conferencing cited the benefits as being quick responses to queries and a reduced feeling of isolation because of the increased ability to communicate with their peers and tutors. Other discussions of the pros and cons of computer conferencing as it applies to distance learning can be found elsewhere (Hoare & Race, 1990; Weedman, 1991; Wang, 1993; Steeples *et al*., 1994; Rimmershaw, 1999).

Taking this concept one stage further was the Virtual Classroom project, the aim of which was to create a system which would provide an 'analogue of the communication forms that usually occur in a classroom' (Hiltz, 1986). Thus, the Virtual Classroom extended the work of previous studies in that rather than simply exploring the effects of a typical computer conferencing system on distance education, the software was developed to enhance a computer-mediated communications system in order to support education (Hiltz, 1993). Making use of the *Electronic Information Exchange System* (EIES), a conferencing system produced at the New Jersey Institute of Technology (Novemsky *et al*., 1987), support tools for distance learners were created to operate in 'adjunct mode', i.e. supplementing traditional teaching methods. Claimed to be the largest such project of its time (Hiltz, 1992), a number of evaluations in the form of questionnaire-based studies were carried out; most of these yielded 'positive' results, although it was also noted that the problem of 'depersonalisation' occurred. This is the situation in which students forget that they are dealing with other people; in this case they were observed to engage in 'highly emotional' electronic exchanges with other students, sometimes exhibiting quite aggressive behaviour.

In a similar vein, the Electronic Classroom (ECR) aimed to provide a communication system which was '*closely patterned after the actual* *environment of the traditional classroom*' (Hesser *et al*., 1992). This included a long-term study into the effects of providing such an environment; preliminary results yielded 'positive attitudes.' Unlike the Virtual Classroom, ECR made use of *UNIX* tools to provide a basis for its email:, conferencing and bulletin-board facilities. A number of novel features were also provided in the ECR: tutors could demonstrate software to their students over the network, and ECR sessions could be recorded and re-run at a later date, enabling lessons to be reviewed and students to catch up on missed sessions.

Much closer to the concept of a Learner Support Environment was *Studienet* which was created by the Open University of the Netherlands (Ellerman *et al*., 1992). The aim of the project was to create an integrated study environment for a particular course in mathematics, which would overcome the 'one-way' nature of traditional distance learning methods. This was achieved by means of a software system which controlled external applications such as word processors, automated the uploading and downloading of material, and provided facilities to support the management and monitoring of student progress. However, little consideration seems to have been given to supporting groupwork, and the system does not fulfil the LSE requirement of being flexible enough to cater for different learning styles.

Web-Based Systems

Since the inception of the World Wide Web (Berners-Lee *et al*., 1994) interest in CAL resources has exploded. Practitioners have advanced arguments supporting the use of the World Wide Web as a teaching resource (for example Ibrahim, 1994; Marshall *et al*., 1994; Ibrahim & Franklin, 1995; Watabe *et al*., 1995):

- it is a widely distributed resource;
- it provides a multimedia/hypermedia environment which could lead to a richer learning resource;
- it is cheap (often free to education) and available on many different platforms.

Another important factor, singled out by the team that was involved in the *COSTOC* programme (see earlier), is that the Web can also serve as a digital library. Makedon & Maurer (1988) identified the need for Computing Learning Resource (CLEAR) Centres which could act as repositories for lessons and tools to aid teaching. A number of research projects have considered the provision of digital libraries (Fox, 1993), an example being Envision (Fox *et al*., 1993). More recent developments such as the release of the 'Internet Programming Language' Java have allowed the concept of digital libraries on the Web to take on another dimension: the creation of libraries of tools and utilities which can be integrated into Web courseware. An excellent example of such a resource is the Gamelan site (Gamelan, 1999), which includes an education area containing Java applets for use in many different subject areas. Another example is the *QUIZIT* online testing and grading system (Tinoco *et al*., 1997), which supplements a large Web-based digital library.

Distributed Systems An example of a service that is typically provided via the World Wide Web is the Cardiff Information Server (Marshall *et al*., 1994). A prize-winner at the First International Conference on the World Wide Web in 1994, the purpose of the project was to develop a system of resources to be used in adjunct mode, providing support for the teaching methods typically employed in a university (lectures, tutorials, and so on). There was no consideration for the support of distance learning. Courses in *C* Programming, *X Windows*, Image Processing and Parallel Computing were all supported by the provision of online courseware including lecture notes, reading lists and student exercises. Other interactive facilities were included via hyperlinks to run programs and view their output.

An interesting illustration of the power and flexibility of the Web as a learning resource was in the use of the Cardiff server on the course on Parallel Computing (Hurley *et al*., 1994). Four separate institutions were involved in this (Kent University, Southampton University, Cardiff University, and Queen Mary and Westfield College), with the facilities available at each centre being used for different parts of the course. For example, the transputer network at Kent was used for the section on Occam and transputers, and the *nCUBE2* at Cardiff was used for the section on algorithms and paradigms. This distributed processing approach neatly exemplifies one of the central arguments for the more general adoption of distributed systems in education.

Another project which made innovative use of the World Wide Web concerned the visualisation of data structures and animation of algorithms for a data structures course in Geneva (Ibrahim, 1994). Also created for use in adjunct mode, no consideration was given to supporting communication between students and tutors, but the implementation offered an impressive range of features. The animation system operated much like a debugger so students could execute a *Pascal* program, examine it step-by-step, place breakpoints in the code and inspect the values of variables. Graphical representations of any data structures which were used within the provided code were also made available. A disadvantage of the method was that programs required modification before they could be run through the animator; this prevented students from directly running their own code through the system, although the team did report an effort to automate the modification process. Since then, interest in the use of animation across the Web has increased substantially; Weblab (Boroni *et al*., 1997) is just one that has claimed success as a learning aid.

At the University of Melbourne, use of the World Wide Web was investigated as a means of alleviating the problems arising from an inability to cope with the demands being placed on the university's computing system (Nott *et al*., 1995). Already making use of multimedia classrooms to overcome difficulties in accommodating students in Chemistry and Biology laboratory classes, the Web was identified as a means of facilitating the distribution of courseware around the entire campus, thus relieving the demand for workstations at specific campus hot-spots. The focus was on delivery rather than interaction, the three case studies which were described being a Physics class in which the Web was used to distribute laboratory notes to students in advance, the design of a graphics-rich course for delivering material to Zoology students, and a further Physics delivery system making use of 'text, dynamic graphics and interaction with tutors.'

One of the most successful systems for creating Web-based educational environments is *WebCT* (Goldberg *et al*., 1996; Goldberg & Salari, 1997), developed at the University of British Columbia and since installed at hundreds of institutions around the world. *WebCT* has three central components:

- a presentation tool, allowing a course designer to make decisions regarding layout, colour, text fonts and so on;
- a set of student tools for use by those taking a course. These tools include conferencing and other communication facilities, and evaluation subsystems such as online quizzes and multiple choice questions;
- a set of tools to aid in the administration of a course. These include student progress monitoring, access control and reporting.

The work on *WebCT* is particularly important with regard to the results that have been obtained on the effects of such Web-based systems. While individual institutions often provide positive feedback (Morss & Fleming, 1998), the creators of *WebCT* offer more intriguing findings. In an earlier study of a course on operating systems (Goldberg, 1997a), they divided the students into three groups, the first taking traditional lectures, the second taking the course entirely online and the third having access to both mechanisms. In terms of academic performance the third group came out on top, with little to separate the other two groups. In a subsequent experiment (Goldberg, 1997b), student reaction to the use of *WebCT* in the third year of a degree course was compared to that obtained in the first year. The results suggested that the first year students were much less impressed than the third years and made far less use of *WebCT*'s facilities. Use of *WebCT*'s conferencing tool illustrates this division nicely, since it was found that 82% of the first years never made a single posting (compared to about 30% of the third years), and one third of the first years never read any articles (whereas all third years read at least one article). It was also noted that the majority of first year students would have preferred to have a full set of printed notes at the start of the course rather than online access.

Distance Learning Systems Even under the distance learning heading, the emphasis has largely been on the delivery of material to students rather than on specialised support for the communications aspects. Perhaps the most well-known of the distance learning projects utilising the World Wide Web is the Globewide Network Academy (GNA) (Butts *et al*., 1994). The idea behind the GNA was to create a fully accredited on-line university making use of the WWW and other Internet systems such as ftp and email. The earliest developments centred on an open learning correspondence course in C^{++} programming. For this, the main use of the Web was for access to online material such as the course text. Tutorials were held via email:. The course also made use of *MOO*s (Multi-user dungeon Object-Oriented), which are object-oriented versions of a Multi-User Dungeon (*MUD*) – an 'adventure game' environment with rooms containing objects and people with which the learner can interact. The system interface was purely text-based.

Following on from the earlier studies into the effects which conferencing can have when used to support distance learning (see above), the Open University (UK) experimented with taking the concept further by running a Virtual Summer School (VSS) in 1994. The purpose of establishing the VSS was to enable students who were unable to attend a residential course to enrol with the school. Making use of a range of software packages, students were able to participate in group discussions and projects, perform experiments, listen to lectures, browse publications, prepare and submit work, take part in one-to-one tutorials, and socialise. The course being used as the test-bed for the study was on the subject of Cognitive Psychology. Conferencing in the system was both text-based and video-based and the students made use of a Web browser to access documents relating to the subject. An evaluation of the VSS deemed it a success as it allowed the students to undertake the same work as those who attended the residential course and it suggested that '*for most students, VSS was a valuable experience*' (Issroff, 1994). However, many students reported difficulties with the software systems provided for them. It was observed, for example (Issroff & Eisenstadt, 1997), that the use of a number of different software packages to implement the system's functionality also introduced a level of instability into the system, leaving it prone to failure.

In a similar fashion to the VSS, *CODILESS* (COllaborative DIstance LEarning Support System) aimed to 'support both collaborative and resource-based learning' (Watabe *et al*., 1995). The project addressed problems associated with text-based conferencing systems, and an environment was created which made use of both synchronous and asynchronous forms of communication, with the Web being used for access to electronic documents. A number of aspects relevant to distance learning received less attention, however, including support for practical work.

Also making use of the communication and information delivery features of the Web was *WEST* (McLoughlin, 1996). This provided a learning environment enabling the remote creation and management of course materials, as well as facilitating communication between the different classes of user – students who take courses, tutors who are responsible for classes, and administrators whose duties include maintaining class lists and course material. Each type of user was given access to different facilities within the system. *WEST* differed from other Web-based learning systems in that it did not rely on static HTML files for its information base. Instead, documents were created dynamically for each user as and when required. Support for practical work extended to utilities for electronic submission of work, using forms into which students typed their answers to exercises. Group work was supported at class level only, each class having its own bulletin board which could be accessed only by class members. Communication between students and tutors was otherwise supported by an in-built email: system and a class announcements page that could be written to only by tutors.

In recent years the makers of conferencing and communications software have recognised the desire for web–based interfaces to their products, with the result that a large range of such systems has become available. Examples include *FirstClass* (used by the UK Open University), *TopClass* (claimed to be in use by thousands of institutions), *Web-Course-in-a-box* (WCB) and *Virtual-U* (Harasim, 1999).

Discussion

There are a number of general observations that can be made concerning the systems described above. At the most abstract level, it may be seen that systems aimed at distributed learning have had a distinctly different focus from those aimed at distance learning. Research into distributed learning systems has tended to concentrate on methods and styles of delivering courseware to students, or on supporting practical work, whereas work on distance learning systems has usually been concerned with facilitating or enhancing communication among students and tutors. That said, a theme common to both camps is the aim to provide adjunct support rather than to replace traditional teaching methods entirely. This perhaps suggests that practitioners are still uncertain as to how to make best use of the new media, and hence that there is a clear need for further investigation in this regard.

In looking at distributed learning systems it becomes apparent that there are two opposing approaches: creating an environment in which courseware can be devel-oped and distributed; and funding and supporting the design and implementation of courseware in the hope that the features of an appropriate environment are thereby revealed. Historically, the former of these two approaches has been the more popular and has led to more effort being channelled into the creation of courseware. It has been noted, for example, that while both the *Andrew* and *Athena* workforces reported the same number of individual projects over a given time period, a number of the *Athena* projects were simply conversions between different platforms (Isaacs, 1989).

Whatever the approach taken, a key lesson that has been learnt is the value of a uniform interface to any courseware which is derived. Teaching systems must be fully integrated and offer a framework in which courseware can be implemented and distributed both in on-campus and in wider-area situations. A case in point is that of the Open University's Virtual Summer School (see above). This project made use of software from a number of different sources, and in the final analysis was observed to be both unstable and error-prone. Not only did the variety of packages prove difficult for the students to install and configure, it was also found that certain combinations of software, when used together, would result in a student's work being interrupted, or the student locked out of the system altogether.

Clearly, both distributed and distance learners can benefit from improved communications support. At a local level, computer-mediated communication can, for example, be used to overcome temporal barriers allowing students to make contact with peers and tutors if they are not immediately available for face-to-face communication. More obvious benefits are derived when there are also spatial barriers to be overcome and it is therefore within this context that most such research and evaluation has been performed. Whilst the majority of studies have reported positive outcomes which support the use of computer-based communication for learning applications, a number of limitations have been noted. An example is the nature of material which can be transmitted as courseware: courses such as mathematics and physics making heavy use of formulae and symbols can prove difficult when a solely text-based medium such as email is employed. Another potential problem is that of depersonalisation, as discussed earlier.

To an extent, the facilities offered by the World Wide Web can be used to overcome many of the problems mentioned above. Its multimedia abilities can certainly be used to overcome the display problems of text-based systems (Majewski, 1999) and, as is suggested in the work of the *CODILESS* team, the problems of depersonalisation. Unfortunately, it is common to find that the use of the Web in many education-oriented systems is confined solely to providing access to electronic versions of course notes. Although there are some exceptions (e.g. the use of the Web for organising and managing team-based projects (Curtis, 1997)), this tends to be true even of local-area networks that could be utilised much more productively. Clearly, Web-based distribution of course notes offers its own advantages – notably reduction in paper and photocopying costs, and simplicity of dissemination – but there are other major issues that are often left unaddressed. Most importantly, perhaps, it needs to be realised that Web usage is not a panacea for the problems of networked teaching; some of the experiences of the *WebCT* creators should act as a salutary caution in this regard. It has been said before that CAL developers too often fall into the trap of thinking that education is a 'bitter pill that can be made more palatable only by sugar coating' (Kay, 1991).

For distance learners the advent of Web-based learning environments such as those mentioned earlier and other sophisticated systems such as *Lotus Notes/Domino*, have led to much improved and more flexible ways of partaking in the learning experience. Recent projects such as CSILE/Knowledge Forum at the Ontario Institute for Studies in Education (Scardamalia & Bereiter, 1996; Smith Lea & Scardamalia, 1997), and Just-in-Time Open Learning[*] in the UK (McConnell & Hammond, 1996) have been founded upon models of distance learning that place enormous emphasis on collaboration, co-operation and communication, making the availability of such software tools vital.

Again, however, it would be premature to assume that these distance learning systems offer the ideal solution; indeed, they may bring with them their own peculiar difficulties. Robin Mason of the UK's Open University has highlighted a number of problem areas (Mason, 1999). For example, conferencing can easily come to be dominated by a small group of individuals unless great care is taken in the design of the course so as to encourage universal participation. Another point made is that, while facilities for supporting collaborative projects are highly valued, extensive use of this approach to learning may necessitate regular, structured and sustained activity at the computer — the very form of working that many distance learners find impossible to accommodate. Finally, the sheer amount

[*] This implementation followed the European JITOL project (see *JCAL* 8:3 and 11:4) which itself drew on a previous study into Open and Distance Learning supported by the Training Agency at Lancaster.

of time and effort that must go into creating and administering distance learning courses should not be underestimated (Goodfellow, 1999).

Increased interaction for distance learners is clearly a worthy goal, but it need not come only in the form of communications technology. Also of importance is to heighten the level of interactivity available in course elements that have a highly practical nature, such as computer programming or experimental work. This is not as infeasible as it might sound: simulation tools can be of great benefit in such areas (Alder *et al*., 1990; Svanaes, 1990; Anderson & Jackson, 1995a; Watkins *et al*., 1995; Livesey, 1997), and some research has been done on problem-based learning support (Anderson & Jackson, 1995b).

Conclusions

Despite the impressive scale of some of the projects described in the previous sections, it is clear that much of the research performed on systems for distributed and distance learning has been narrow in scope, in that the approaches and systems have focused on highly specific facets of the CAL problem such as the needs of a particular course, means of communication, provision for practical work, interactive demonstrations, and so on. This is not a criticism, but recognition of the simple fact that there is still much work to be done and many problems to be overcome before general-purpose CAL frameworks become available. What is yet to be attained is a true Learner Support Environment (LSE) – an integrated system which can draw upon the experiences of these earlier developments and yet offer a flexible solution easily adaptable to a variety of student and course needs.

Part of the problem is that any generalised solution would have to be able to cope with a wide range of learning styles. Many different learning styles have been identified; indeed, Messick (1976) listed 19. However, other researchers have pointed out that these styles lie on a continuum ranging from learning with a guided system of predefined structure to unstructured learning in which students are free to explore and discover facts (Clarke, 1990; O'Malley & Scanlon, 1990; Allinson, 1992). It has been observed that learners tend to move from the structured and guided style to the exploration and discovery style as their knowledge of a subject area increases (Clarke, 1990). It has also been noted that structured, guided styles are best served by presentation-type CAL and that unguided discovery learning is best aided by simulation or game-type CAL. Such insights are invaluable, and it is perhaps with further such research into learning styles that future advances may be made regarding the creation of improved learner support tools.

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