E-Learning

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Abstract
E-learning as a term and its application in the support of learning has evolved considerably over the last ten or more years. This evolution comes from a noticeably different approach to learning by early adopters, as dictated by the technology of the time.

In order to bring the reader up to date with the role and use of e-learning and its associated technologies this article will review the meaning of e-learning as it evolved from little more than reading electronic books to today's concept of 'anytime anywhere' learning supported by the Web. It will attempt to clarify some of the confusing terminology surrounding e-learning and provide a basic introduction to some types of technology used to support learning. In addition some examples of the use of e-learning within the physical sciences will also be reviewed along with some pointers to current publications and national initiatives for up to date information about how e-learning is being used in higher education.

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What is e-learning?
The rapid expansion in the development of computer technology in the 1980s and 1990s and the associated reduction in costs made it possible for computer supported teaching to enter mainstream education. However, many early educational resources were little more than electronic books. In 1989, the World Wide Web was invented by the physicist Tim Berners-Lee but it was not until about 1993-95 that it matured enough as a technology to be integrated into conventional education.

Thus from computer based instruction, where the student was sat at a computer working methodically through mostly linear content; this development in computer based resources suddenly opened up exciting new avenues for flexible, computer supported learning. With the now breath-taking developments of other computer technologies that link into the Web, the term e-learning has emerged to mean learning supported by computer technologies. This is different from traditional definitions such as ‘computer based training’ which was often little more than a bolt-on to traditional face-to-face teaching. E-learning made learning more interactive and could be tailored to suit different learning styles. Therefore, e-learning may be defined as ‘teaching and learning supported by technology and based on sound pedagogical practices’.

Terminology and definitions
It is an old adage that you don’t need to understand the workings of a car engine in order to drive: so it is also not important to understand much computer terminology to engage with e-learning. Indeed, an attendee at a recent workshop on e-learning commented: “[sic] Understanding that I had been using blended learning for years without knowing it!” Blended learning is a term that is becoming increasingly used in conjunction with e-learning and refers to the notion that you combine, or blend e-learning with face-to-face learning.

In order to try to put computer terminology into perspective, it is perhaps best to consider the important aspect of e-learning, which is the focus on ‘learning’. A teacher will use a variety of methods to support student learning so e-learning and all the technologies that go with it, can best be understood from this perspective.

A useful starting point is to consider what you want to do to support students through e-learning and then to consider the use of technology. For example, do you want to give students better access to electronic communication tools in order to promote group discussions? Once you know what you want to do you can find out what the associated technology is called and then how to use it. The next part of this article will review a number of new and developing technologies in an attempt to demystify much of the confusion surrounding their use, particularly for education.

Types of technologies available

Virtual Learning Environment (VLE)
VLEs encompass a range of utilities in one system to provide a learning experience in a virtual (online) setting. VLEs commonly provide a web interface to provide access to content and files to support student learning. They also provide a range of tools including email and discussion boards for communication. There are sometimes interactive tools such as 'live' communication tools and shared whiteboard tools for synchronous communication; and assessment tools which also provide students with results, feedback and other course information.

Simulations and animations
In many subject disciplines, not least the physical sciences, the use of simulations has great benefits for the visualisation and representation of concepts that can sometimes be difficult to explain. Laboratory simulations can also be of great benefit to students, allowing them to repeatedly run experiments that would otherwise not be possible in a real lab, due to time, cost, safety etc. One popular animation program called *Flash* is produced by Macromedia (bought by Adobe in Dec 2005). *Flash* allows authors to create interactive simulations relatively quickly. Other examples of the use of animations and simulations are provided in a 2006 workshop summary report from the Physical Sciences Centre entitled 'Producing Animations & Simulations' (see 'Further information and links' for details).

Video streaming
Video offers a number of educational benefits but downloading video clips can be slow. One way around this is to use video streaming, whereby the video starts to play as it downloads and continues to play as the next bit of the video is downloaded. This requires a dedicated video streaming server – a specialist computer server for delivering video which is a commonly used and readily available technology. Information, advice and examples of video streaming use can be found at the e-Learning Centre, a non-profit organisation based in Sheffield (see 'Further information and links' for details).

Podcasts
A podcast is the broadcast of video or audio across the internet. A podcast is different from a simple download of audio or video from the Internet, such as video streaming because these offer the media files only once and when the broadcaster chooses. Podcasting is a subscription service where the user downloads the files as and when they wish and is provided with automatic updates to the broadcast. This makes mobile access to media much more personalised. Podcasting is still relatively new but is starting to gain interest in education with a variety of resources being offered. Although some may question the practicality of such offerings, some tutors are offering podcasts of their lectures. However, such podcasts certainly may offer benefits to disabled students or act as a useful revision aid.

Wikis
The term 'Wiki' has come into popular use in recent years perhaps largely because of media interest in its use. A wiki is essentially a type of website that allows the reader to edit, add or delete content (depending on restrictions) without permission from the website owner. One of the benefits of a wiki is that it can encourage collaborative writing, hence the media interest.

Blogs
The term 'blog' is a concatenation of the words web and log, an early description of people keeping online logs of discussions on various topics, hosted on web pages. A blog operates through the production of a blog website which requires a special blog server that enables posts to a blog to be categorised (by time, date, author etc). Individuals can often now get free hosting of their own blogs from host suppliers.

In education blogs are gaining interest, perhaps because students are used to using the technology for social purposes. To use a blog in an educational setting the teacher can create a blog outlining the content to be covered or discussed along with any associated links to resources. Students can interact with the blog, recording their thoughts and offering feedback; the blog ultimately develops into a resource in its own right.

Examples of e-learning in the physical sciences
A good starting point for finding examples of the physical sciences academic community actively engaging with e-learning is through the Physical Sciences Centre. Since they are in close contact with the academic community the Centre is aware of many of the good examples of the use of e-learning in chemistry, physics and astronomy. The Centre also runs national events to bring together practitioners of e-learning in order to share their experiences.

One such workshop run in 2003 in Cardiff (Using Virtual Learning Environments to Support Learning and Assessment) brought together speakers from around the UK to discuss their use of VLEs. Speakers discussed how they had developed and used a variety of resources to support student learning and discussed the various merits of VLEs. Another key aspect of the day was a review of computer assisted assessment (CAA) and how various speakers were using CAA to support their students.

A more recent event was run by the Centre in Edinburgh in 2006 (Flexible delivery and e-learning). Here speakers from institutions around the UK talked about their use of e-learning - testament to the expanding and widespread adoption of e-learning in the physical sciences. Speakers demonstrated how they had developed e-learning resources as part of specific modules for their courses (blended learning) but also for whole courses delivered entirely online. Further details and reports about both events and other information and links for e-learning can be found from the Centre's website, details of which are given below.

One example of a departmental approach to the integration of e-learning into the curriculum is that taken at the School of Physics in Edinburgh University. Simon Bates is a key member of staff there who has undertaken a lot of innovative work with e-learning and other related technologies, such as the use of electronic voting technology. Simon also offers sound advice through a set of principles for the successful adoption of e-learning, which are described in his talk that was given at the Edinburgh event and in the review in this journal.

At an international level, there are approximately 50 Physics Education Research (PER) centres located in universities and colleges across the USA. These actively engage with formal research into the development of e-learning to support physics teaching. One outlet for the results of their work is in the American Journal of Physics. As stated on the website at the University of Maryland's PER group: "The *Physics Education Research Section of the AJP* is intended for the presentation of research results on the scientific investigation of the learning and teaching of physics. This section is meant to serve both as an archival forum for the presentation and discussion of issues among physics education researchers and as a place for those interested in 'what works' in physics instruction."

Another example of the use of e-learning, this time to support chemistry teaching is the development of an online module produced at Manchester Metropolitan University. The focus of their work was "the promotion of active student participation within this online-learning module". The development of this work was supported through project funding from the Centre. A number of important considerations are listed such as adopting a structured approach to learning: using a variety of teaching and learning styles, eg online student workshops and overview lectures; and supervised independent learning sessions. The full report of this development project is available from the Centre's website under the 'Development Projects' section.

Research evidence supporting educational benefits of e-learning

Early adopters and evangelisers of e-learning were often viewed by many with caution: the perceived benefits of e-learning were often anecdotal or even outweighed by the disadvantages they produced. These drawbacks included problems such as a long development time to learn technical skills and a lack of evidence to suggest that e-learning had any real benefits for learning. This would exclude any placebo effect of students engaging with a different approach to teaching and learning practice. However, there has now been much more formal research undertaken to address the question of whether e-learning can offer educational benefits for academics and students alike.

Whilst there has been extensive general research on the benefits of e-learning there has also been discipline specific research relating to the physical sciences. Gorsky et al[1] have recently explored for the Open University in Israel how students adopt particular learning styles in a chemistry course with online support. Gorsky et al[2] also explored this with a distance physics course. Whilst not explicitly focused on e-learning it discusses how students interact at a distance - something key in an online (e-learning) community.

This is explored in more detail by Lyall[3] suggesting that a computer based learning programme could offer some benefits over print as long as they support the appropriate student learning style.

In another study on the effectiveness of e-learning Morgil et al[4] compared traditional and computer assisted learning approaches for teaching fundamental topics in chemistry. Students undertook pre and post tests after being exposed to 'computer-assisted teaching'. Students in the study showed a 52% increase in post test scores after being supported with computer-assisted teaching. This compared with only a 31% increase for the control group who did not experience the computer support. These results suggest that students engaging with computer assisted approaches benefited more than students who did not use computer supported learning.

Pol et al[5] discuss their research findings into how computer based instruction can help improve problem solving skills. They suggest that content from textbooks helps develop 'declarative and procedural knowledge' but not problem solving skills. By engaging students in a computer based resource on the topic of forces they found that students achieved higher results in problem solving than the control group who did not use the computer resource.

The research reviewed so far demonstrates two developments. The first is that the use of e-learning is becoming widespread and in some cases, mainstream in the teaching of physical science. The second development is that this research shows that physical scientists are not just accepting the benefits of e-learning at face value but are actively engaged in adopting e-learning based on tried and tested practice. This review will now consider a few examples of particular aspects of e-learning in use within the physical science curriculum.

Simulations

With the ever evolving capabilities of technology Barab et al[6] describe an early innovative use of Virtual Reality (VR) for an astronomy course. Students engage with VR technology to develop 3-D models of the solar system to help 'build rich understandings of various astronomical phenomena'. The work was undertaken as two case studies to evaluate a number of aspects of introducing technology into teaching, but a major outcome was that they found it effective in helping students engage with astronomy in undergraduate courses.

Another relatively early development of computer simulations to support student learning is documented by Littlejohn et al[7] with their development of an online chemical structure modelling tool. This web-based tool allows students to simulate the production and manipulation of chemical structures in a carbohydrate chemistry course. The benefits afforded include the ability for students to learn by 'trial and error' with adaptive feedback on their progress. One conclusion they draw is that technology has the potential to improve the *quality* of the learning experience.

Computer simulations are also the focus of a study by Jimoyiannis and Komis[8] to 'support powerful modelling environments involving physics concepts and processes'. This study explores the benefits of students' understanding of trajectory motion using software called *Interactive Physics*

which simulates fundamental principles of Newtonian mechanics. Their results demonstrated yet again, that students who engaged with the technology achieved higher scores on tasks than the control group who did not engage with the simulations.

Discussing the use of animations and simulations from a chemistry perspective, Tasker and Dalton[9] consider how student misconceptions of a topic can arise from an inability to visualise structures and processes. However, these misconceptions may not be dispelled simply by showing them a visual model. These animations "can be compelling and effective learning resources, but they must be designed and presented with great care to encourage students to focus on the intended 'key features', and to avoid generating or reinforcing misconceptions".
Based on this understanding Tasker and Dalton[9] discuss how informed by their research findings they developed the *VisChem* animations to demonstrate chemical reactions at a molecular level.

Bruce Sinclair at St Andrews University has a collection of computer simulations for physics, which are freely available resources. This site is referenced below in the further information and links section. Another site, with other resources is the Physics Educational Technology website, again listed below.

Laboratory work
Although aimed at pre-university students, a study by Barton[10] explores the possibility of supporting teachers to innovate in physics teaching through the use of computer-aided practical work. This study explores the issues surrounding the development and integration of computer-aided practical work into the curriculum. This work raises an interesting point about a teacher wanting to attempt innovation on their own without support. It suggests that innovations can best be supported with a researcher more familiar with both the technology itself and the methods of teaching with the technology. This would provide valuable support for the teacher in becoming familiar enough with the process to be able to adopt it themselves.

Work by Burewicz and Miranowicz[11] looked at developing a strategy of using 'computerised assistance for laboratory experiments' by developing 'pre-experimental, syn-experimental and post-experimental function[s]'. This was based on an experiment concerned with 'empirical equations of reaction kinetics'. This research investigated the effectiveness of multimedia laboratory instruction on the outcomes of student practical skills. The authors found that the use of computerised laboratory multimedia instruction increased the student level of practical skills (more so than even the use of video instruction) and that fewer experimental errors were made. In addition, they found that students actually had to spend less time completing the experiment in the laboratory.

Another study that supports the work of Burewicz and Miranowicz[11] is by Waller and Foster[12] where they use the Web to develop a simulation of an experiment using a gas chromatograph-mass spectrometer. Students can use the online interactive equipment to simulate the experiment before actually going into the laboratory and using the real equipment. The authors found that this reduced the amount of in-lab tutorial time needed to familiarise the students with the equipment and enabled much more efficient use of their time whilst in the laboratory. Staff also reported that students were more confident using the equipment after having engaged with the virtual instrument.

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Computer assisted assessment
Computer assisted assessment (CAA) has been around for many years and has often had positive reports, though the technical implementation of CAA is often fraught with difficulties. Potential gains made in helping the student learning process by adopting CAA are sometimes countered by the increased workload for the academic in having to become familiar with the technology. There are also potential administrative headaches when CAA does not provide for the automation of marking and feedback.

Ashton et al[13] explored any effect of CAA on students' computing ability and performance in chemistry compared with paper based tests. The authors found that there was no medium term difference between CAA and paper based tests. In addition, with the re-wording of the questions for electronic delivery there was a risk that this might influence outcomes. This was also tested and no influence was found so Ashton concluded that CAA provided no difference from paper based tests.

These results can be viewed in two ways. The first is that CAA has no benefit over and above that of paper tests. Any possible time and other administrative savings by using CAA were not discussed so it is not possible from this study to determine if CAA can bring any administrative benefits. The other approach to these results is to suggest that if CAA is no less effective than paper tests then there is no reason not to adopt CAA. Additionally, if it can be shown that CAA can bring administrative benefits such as reduced time for marking and providing automated feedback then CAA has the potential to offer real benefits to both students and academics.

In another study on the effectiveness of CAA on student performance, Lowry[14] compared two groups of students and measured their results. Students using CAA could access the materials any time and two levels of feedback provided guidance to further learning. The results showed that students using CAA performed significantly better than the control group who did not use CAA, suggesting that CAA had a positive impact on student learning.

There is also a lot of international interest in exploring the effectiveness of CAA in the physical sciences. Diederen et al[15] from the Netherlands reported their work on the "Evaluation of computer-based learning material for food chemistry education". This paper discusses the design requirements for digital exercises with respect to the users' needs and found that the students found them useful and helped with their preparations for exams.

Keeping up to date with e-learning developments

There are a number of ways to keep up to date with the continual developments in e-learning use in the physical sciences. The JISC (Joint Information Systems Committee) funded by UK FE and HE funding bodies is one of a number of national initiatives and organisations that address e-learning. They regularly host events and conferences, and offer "strategic guidance, advice and opportunities to use ICT [Information and Communication Technologies] to support teaching, learning, research and administration". Due to its technically oriented nature, the JISC undertakes much of its work in support of e-learning development and provision.

A number of Centres for Excellence in Teaching and Learning (CETLs) related to e-learning were funded in 2005. In particular, the Centre for Open Learning of Mathematics, Science, Computing and Technology (COLMSCT) has a focus on assessment and e-learning in the sciences.

There are a number of national and international organisations that promote the use of e-learning, but perhaps two UK organisations to note are the ALT (Association for Learning Technology) and the CAA (Computer Assisted Assessment) Conference. Both offer hugely popular conferences each year that bring together academics from a wide range of subject disciplines to present work on the use of e-learning within their own institutions. ALT is also a membership organisation with its own peer reviewed journal.

There are several journals which address e-learning research, some with a specific focus on the sciences. The *American Journal of Physics* has already been mentioned but there are also journals such as *Chemistry Education Research and Practice*, produced by the Royal Society of Chemistry and *Physics Education* by the Institute of Physics. Others include the *International Journal of Science Education* by Taylor and Francis, *Computers and Education* by Elsevier and *British Journal of Educational Technology* by Blackwell Publishing.

One other (freely) available service perhaps worth mentioning is Google scholar. This provides the opportunity to search across subjects for "peer-reviewed papers, theses, books, abstracts and articles, from academic publishers, professional societies, preprint repositories, universities and other scholarly organisations".

Closing remarks

The integration of e-learning into the curriculum can be a daunting prospect. There are a plethora of technologies available and at first sight it might seem that a degree in computing is required just to understand it all. However, it is important to use e-learning for specific educational purposes and not just because the technology exists. The best way to engage with e-learning is to consider how technology might support your teaching, say by offering benefits through online communication or using computer simulations to explain a difficult concept. The next step is to simply trial it, but with a proper evaluation process in place to determine how well it worked for the intended purpose. This approach coupled with seeking the advice and help of colleagues who are already engaging with e-learning is a good way to start engaging with e-learning so that it offers real educational benefits for both you and your students.

Further information and links

Flexible delivery and e-learning workshop report, Edinburgh 21st Feb 2006
http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=78 (accessed 18/04/06)

Using Virtual Learning Environments to support learning and assessment, Cardiff 19th Nov 2003 http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=52
(accessed 18/04/06)

Producing Animations & Simulations, Hull 29th March 2006
http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=81
(accessed 10/10/06)

e-Learning Centre
Streaming e-Learning/Webcasting
http://www.e-learningcentre.co.uk/eclipse/Resources/streaminglearning.htm
(accessed 10/10/06)

E-learning at Edinburgh
http://www.elearn.malts.ed.ac.uk/
(access 24/07/06)

Simulations in physics and astronomy
http://www.st-andrews.ac.uk/~bds2/ltsn/index.htm
(accessed 18/04/06)

Physics Educational Technology
http://phet.colorado.edu/web-pages/index.html
(accessed 10/10/06)

Flash
http://www.macromedia.com/software/flash/flashpro/
(accessed 18/04/06)

Centre for Open Learning of Mathematics Science, Computing and Technology
www.open.ac.uk/colmsct
(accessed 10/10/06)

The Association for Learning Technology
www.alt.ac.uk
(accessed 10/10/06)

International CAA Conference
http://www.caaconference.com
(accessed 10/10/06)

American Journal of Physics
http://scitation.aip.org/ajp/
(accessed 10/10/06)

Chemistry Education Research and Practice
http://www.rsc.org/Education/CERP/
(accessed 10/10/06)

Physics Education
http://www.iop.org/EJ/journal/PhysEd
(accessed 10/10/06)

International Journal of Science Education
http://www.tandf.co.uk/journals/tf/09500693.html
(accessed 10/10/06)

Computers and Education
http://www.elsevier.com/wps/find/
journaldescription.cws_home/347/description
(accessed 10/10/06)

British Journal of Educational Technology
http://www.blackwellpublishing.com/journal.asp?ref=0007-1013
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