E-learning as technology, e-learning as learning

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Abstract
This paper explores two main themes: Firstly, it examines what we understand about the economic, technical and social impacts of new technologies and examines how this might relate to the complex range of technologies that fall under the title ‘e-learning’. It argues that detailed exploration, using foresight methods, of the likely impacts of various e-learning technologies is a key task.
Secondly, understanding of how learning happens, from a constructivist viewpoint, is used to develop a set of criteria against which e-learning approaches can be judged. The paper concludes by applying the principles developed to the case of e-learning in electronics within D&T.

Key words
E-learning, learning, ICT, new technology, impact, D&T, electronics simulation software, microcontrollers

Biography
Torben Steeg is a freelance consultant in education, specialising in curriculum development, evaluation and research in Design & Technology, Information and Communication Technologies (ICT), Science and Mathematics. He is also an Honorary Research Fellow in the University of Manchester Faculty of Education where, until January 2004, he was Subject Leader for the PGCE D&T course, supported the development of students’ understanding of ICT use across all PGCE courses and taught on the MEd in ICT course. He is external examiner for the PGCE and KS2/3 D&T courses at Liverpool John Moores University. Research interests include the interactions between D&T, ICT, Science and Mathematics, the use of the Internet in schools and, within D&T, systems thinking, control technologies and the uses of ICTs to support learning. He works with the Nuffield D&T Project and is a member of the editorial boards for the IEE’s ‘Electronics Education’ and DATA’s ‘Journal of D&T Education’. He is also a member of DATA’s ITE Advisory Group and an accredited trainer for Pro/DESKTOP and for the ECT initiative. Previously he taught D&T, Control Technology, Science and IT before moving to the University of Manchester, initially to work with the Technology Enhancement Programme.
This paper explores two main themes: Firstly, what we understand about the impact of new technologies and how this might relate to e-learning as the application of a range of new technologies. Secondly, our understanding of how learning happens and what the implications might be for ‘e-learning’. The paper concludes with a brief application of the issues raised to a particular instance of e-learning.

The impact of new technologies

It has been common for some years now to use the letter ‘e’ as a prefix to signal a familiar activity being carried out using electronic technologies and, in particular, Information & Communication Technology (ICT). E-mail, e-commerce, e-gambling, e-books, e-banking and, of course, e-learning are familiar examples and the purveyors of each new ‘e-’ prefix seem keen to imply two things;

1. That the transfer of the activity from the physical to the electronic domain is unproblematic;
2. That this transfer will fundamentally, and for the better, transform the activity.

Fostering such feelings towards these new technologies presumably makes sense from the perspective of those promoting them; they may view potential users as potentially conservative in their habits and, in particular, cautious about transferring activity from a known realm to one that is unfamiliar and intangible. Often the imperatives for change are financial so that moving people onto new systems as quickly as possible is highly motivated by economics.

However, both of the above claims are generally challengeable. Transfer of an activity from one domain to another is unlikely to be completely unproblematic and, while this transfer may indeed transform the activity, whether this transformation is ‘for the better’ or not relies upon value judgments and questions of ‘better for whom?’.

Moreover, the two implications contain the seeds of a contradiction; is it likely that a transformation of the way an activity is carried out will be unproblematic? On the whole it seems likely that the more fundamental the transformation the more likely it will be that unforeseen problems will develop in the process of transfer.

E-mail is an example of an electronic technology familiar to many people (but by no means at all to all people, even in supposedly ‘wired’ societies such as the UK). Is the transfer to e-mail from other, paper-based, forms of communication unproblematic? The answer has to be ‘no’. Brief consideration of e-mail as a technology reveals problems in the economic, technical and social arenas.

A fundamental economic problem is clear; access to e-mail is predicated on access to costly and technically complex Internet infrastructure and technology. It is easy to forget in the affluent North, as we juggle our phones, and decide whether to communicate by SMS, fax, e-mail, instant messaging, blog, or voicemail, that in some areas of the world access to a phone remains a luxury. Even in richer countries there is concern about the ‘digital divide’ between those who do have easy access to Internet technologies and those who don’t.

Those who do have economic access to the required technologies may still find that e-mail is not necessarily a straightforward technology to master. Internet technologies, and, I believe, computer technologies generally, remain immature technologies; by this I mean that they are neither intuitive to use nor technically robust. The majority of e-mail users in the UK rely either on technical support at their workplace to set up and maintain a reliable e-mail service or on pre-installed or automatically installed (e.g. from a CD-ROM) services to set up e-mail (but not maintain it) on their home computers. The problem, for the majority of non-technical users, with the latter is that the very necessary maintenance to keep a modern PC
running effectively is expensive. The experience of most PC owners is that performance and reliability degrades over the first six to twelve months – and this affects access to e-mail.

For those with effective access, e-mail has had a significant social impact. It transpires that, although e-mail appears to have similar aims to traditional postal mail, the differences are such that people generally approach the business of e-mailing others quite differently. It will take a longer perspective than we yet have to identify the full ramifications of this, but we can identify some issues that seem important now, while accepting that the landscape is still changing. These include:

- An increase not only in the actual speed of communications but also in our expectations of speediness in response to our own e-mails.
- Huge growth in the number of communications we have to deal with every day. This is compounded by;
- Not only spam (deliberate mass junk e-mail) but volumes of irrelevant e-mail because it cost nothing to send an e-mail to multiple recipients, which leads to;
- A growth in the time spent simply managing e-mails. In particular managers who used to delegate paper mail to secretaries have often kept hold of their e-mail management.
- The use of e-mail as the commonest pathway for viruses and similar software into computers, requiring;
- A need to constantly update computer software to prevent viral infection of computers.
- A blurring of the work/leisure boundary as e-mail, along with other new technologies, has made it easier to work not just at home but on most forms of transport as well.
- A terseness in communication urged partly by the speed of the technology but also by the volumes of e-mail that need to be processed.
- Concerns about privacy, as Government lays down rules about the number of years that e-mails must be stored for (even when users have deleted them from their own computers). Interestingly, it remains inconceivable that a Government should attempt to impose the same rules on paper communications; it seems that with e-mail they have because they can.
- Embarrassment as rashly worded e-mails are instantly sent leaving no opportunity to reflect and revise; as e-mails are sent to the wrong people, or to groups of people instead of individuals; or as assumed to be private e-mails are circulated round the world – because it costs nothing to do so.
- There has been a reduction in face-to-face meeting of colleagues in workplaces as a quick email replaces a walk and a chat.

Clearly there are also social benefits that e-mail has brought – or people wouldn’t persist with its use in the face of the issues noted above. These benefits are not listed here, as the aim has been to illustrate how a reasonably simple technology is having a significant social impact on the lives of many people in ways that were neither desired nor predicted (nor probably predictable) by the inventors of early e-mail systems and are not welcomed by e-mail users today. It’s noteworthy that e-mail has not done away with the postal service (or, yet, internal paper mail in most companies); rather it has added another layer of communication that complements (or in the worst cases duplicates) other communication channels such as the letter, the memo, the phone and the fax.

As an aside, it is interesting that SMS (texting), which can be characterised as a highly mobile ‘e-mail lite’, has been phenomenally successful despite being a feature of mobile phones that was, initially, neither planned nor advertised for consumer use. In this case there was no single prior activity that texting has replaced; rather, as with e-mail, a range of prior technologies have been sidelined some of the time. More importantly, texting has created a novel method of communicating that satisfied
previously unrecognised communication desires or needs and enabled new, less
planned, ways of living day-to-day life, so transfer of an activity from one domain to
another has been less of an issue. As with e-mail there are access issues arising
from economic factors, but the economic threshold for access is substantially lower
as is the competence threshold for operation, while, because phones are simpler
devices, their technical maturity is higher than that of desktop computers.
Nevertheless I’m sure that a list of undesirable social outcomes could be drawn up,
not least by teachers.

Why all this discussion of e-mail in a paper on e-learning? Because e-mail is a
technology that is reasonably well understood and familiar, with an apparently
straightforward aim (communication) whose social impact is becoming evident to us.
Consideration of the issues surrounding e-mail in the economic, technical and social
arenas serves as useful warm-up to thinking about the relationship between learning
and e-learning. In contrast to e-mail, e-learning can be based on a wide range of
technologies that few understand well and that are rapidly developing, has an aim
that is acknowledged to be complex to achieve (learning) and is likely to have social
impacts that, though difficult to fully predict, will probably be of deeper significance
than the impacts of email.

Perhaps one useful outcome from this conference might be the detailed exploration,
using foresight methods, of the likely economic, technical and, in particular, social
impacts of various e-learning technologies. It is the nature of impact predictions that
they are guesses into the future; many will be familiar with famous predictions from
the world of computing such as that of Microsoft’s Bill Gates in 1981 that "640K ought
to be enough computer memory for anyone" or the prediction from Popular
Mechanics magazine in 1949 that "Computers in the future may weigh no more than
1.5 tons.". Whatever the risk of looking foolish in the future, we are not absolved from
the responsibility of examining carefully the potential impacts that the new
technologies we introduce into education might have.

Learning and e-learning
Learning is generally agreed to be relatively permanent change in the behaviours,
capabilities, thoughts, or feelings of an individual that results from experience. The
basis of learning is change in the neural structure of the brain that is still not well
understood, although neuroscience research is currently making rapid progress in
uncovering aspects of how learning happens.

E-learning is exactly the same; that is to say the end result of e-learning is learning
because change in the brain has occurred. The ‘e’ in e-learning simply indicates that
a relatively novel medium (ICT) is being used to support learning. It is e-learning as
opposed to book-learning, or lecture-learning, or field trip-learning, or practical
experience-learning. In the same way, the end result of e-mail (a written
communication delivered to a recipient) is the same as postal mail or hand-delivered
mail, even though the process of delivery and the form of the communication is rather
different.

Two things make e-learning both more interesting and more complex than the raft of
other ‘e’- technologies. The first of these is the question of how learning is actually
encouraged to happen – not in the neuroscientific sense but in terms of cognitive
psychology; that is, the methods by which learning can be most effectively
stimulated. The second is the increasing power of the underlying computer
technologies to both simulate the repertoire of teaching approaches that can
stimulate learning. There is potential, in this simulation, to improve the quality of at
least some of these teaching approaches.
Cognitive psychology is an active and somewhat contested field of endeavour. However, in a broad constructivist view of learning, a range of features of learning are generally agreed that can be summarised as:

- Learners construct their own models of the world from their experiences in it.
- The resulting mental constructs are highly individual.
- These mental constructs are robust.
- Social interaction plays a significant role in the construction of mental models.
- Thinking about how you think (metacognition) can improve learning.

Such a model of how learning happens has some key implications for how teaching should be organised. These can be outlined as:

- Teachers ought to elicit not just what pupils know before embarking on teaching, but the context of that knowledge in the pupil’s worldview.

However, this elicitation is not straightforward. Asking a pupil to articulate their knowledge will not necessarily result in them saying what they actually believe (research on undergraduate physicists’ understanding of physics concepts has shown that it is quite possible to answer physics exam questions correctly and gain a place on a university physics course while maintaining scientifically incorrect understandings of fundamental GCSE level concepts). Where pupils do accurately report their understanding they are unlikely to be able to describe the mental constructs in which these are held.

Many teachers are having some success in using tools such as mind or concept maps to help them elicit pupils’ prior knowledge. Some subject teachers (e.g. of Maths or Science) can make use of quite detailed research-based information on the range of prior concepts that pupils are likely to have at particular ages. It is likely that the majority of teachers rely on their training and subsequent experience to inform them of the likely subject constructs that pupils will bring to particular topics.

- Teaching based simply on the transmission of knowledge is unlikely to result in change in these robust mental constructs. Rather, teaching requires the creation of situations that allow pupils to actively develop or re-order their mental constructs. A wide range of these ‘active’ learning approaches have been developed and are in wide use in schools. Their use has also been incorporated into national initiatives such as the KS3 Strategy.

In some cases, successful re-ordering of mental constructs may require the creation of ‘cognitive conflict’; the deliberate setting up of situations to reveal flaws in existing mental constructs.

The inherent robustness of mental constructs means that change may require pupils to have multiple opportunities to experience cognitive conflict spread over long periods of time. For example a ‘spiral’ curriculum is designed so that subject matter is revisited a number of times during a key stage with increasing cognitive demand and in a widening range of contexts.

- The individuality of pupil’s mental constructs is fundamental to the need for differentiated teaching. Differentiation, like active learning, is well explored field, but high quality differentiation remains a demanding expectation for teachers operating in the traditional 1:30 setting.

- Social engagement is central to the construction and reordering of mental constructs. Pupils need a lot of opportunity to engage with active learning in settings that encourage talk; in pairs and groups, in informal and formal settings, to each other as well as the teacher (or other subject authority).

One of the most strongly expressed findings of the APU’s work on D&T was that:

“...There are few things in life that are certain, but one of them is that the occasional use of paired and/or small group activities, and the use of short
but structured discussions, will enormously help pupils to make progress in their work”

The engagement of pupils in metacognition has been shown to make a significant difference to their learning. In recent years a range of projects have provided materials for schools to encourage metacognitive activity, including some that are focussed specifically at Science and at D&T classrooms. Metacognition is also a key strand in the KS3 Strategy. Yet amongst all this activity it is not clear that work in D&T, in particular, is used as matter of course to engage children in thinking about how they think.

A summary of the lessons from cognitive psychology provides an interesting set of criteria against which we might judge any approach to e-learning:

1. Does it support learning through concrete experience?
2. Does it encourage active engagement with the subject matter?
3. Does it support the elicitation of prior understandings?
4. Does it allow for the fact that progression is not necessarily sequential?
5. Does it allow work in a range of contexts?
6. Does it support metacognitive activity?
7. Does it provide opportunities for pupils to ‘talk’ so that learning is embedded, for example within small groups or large groups, one-to-one, or to oneself (for example in a process diary)?

To pick a bad example for submission to these criteria, an e-learning approach that was particularly fashionable in UK schools the 1990s was the Integrated Learning System (ILS). This was very close to what we now call a Managed Learning Environment (MLE), some 10 years later, the main difference being that ILSs were built on proprietary technology rather the ‘open’ Internet technologies used by modern MLEs. The model for teaching proposed for ILS systems was that a group of pupils would sit, individually, at a computer screens, wearing headphones (as instructions were given both as text and voice) and responding to questions provided by the computer system.

An ILS fails on criteria 1, 4, 6, 7 and only weakly meets criteria 2 (the engagement is active within the limitations of on-screen activity), 3 (many ILS systems have a system of establishing the level at which a pupil is working, but this is based on what the individual can do on-screen and is not able to probe understanding in any deep sense), and 5 (most ILS systems provide a range of on-screen contexts). Not surprisingly, the extensive evaluations of ILS systems carried out in the UK concluded that they were only effective (if at all) when firmly embedded within ‘traditional' teaching approaches or, to use a current idiom, within ‘blended’ learning. More damning was that the evaluations found it hard to establish significant learning gains at all, which must have a disappointment to the schools that spent tens of thousands of pounds on dedicated servers, dedicated computer suites and software licences with, it must be said, a great deal of encouragement from UK Government agencies. It is, presumably, safe to assume that no-one in these Government agencies undertook an initial evaluation of the software's potential against learning criteria such as those above before encouraging schools to purchase.

I hope that another outcome from this conference might be the detailed analysis of various learning technologies against the kinds of constructivist learning criteria outlined above.

An example of e-learning

New technologies can drive curriculum change as much as the desire to do new things in the curriculum can drive the development of new technologies. When these forces operate in concert there can be overwhelming pressure to both adopt the new technology and to transform the curriculum in the light of this technology.

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The teaching of electronics in D&T is in the process of such a transformation in the UK. New technologies that allow a great deal of design and development work to be done on computers rather than with physical components are working in concert with the desire to open up electronics to a much wider section of the pupil population. Specifically, two key e-learning technologies are:

- **Electronics simulation software**
  This allows circuits to be simulated and validated on the computer screen. Systems based approaches for those new to electronics and component based approaches for more advanced users are available. It is now possible to design a circuit on screen, test and validate its operation using the computer, automatically transfer this design into printed circuit board (PCB) design software and then use the PCB software to create files that will drive CAM (computer aided manufacture) machinery to produce and drill the circuit board. All the pupil has to do in the physical world is solder the components into place.

- **Microcontrollers**
  These are low cost (around £1) computers on a chip, containing processor, memory, and input and output control. These are the devices that now populate and control a wide range of everyday electronic devices from kettles onwards. One particular version, the PIC, is proving particularly popular in UK schools. A wide range (around 10) of competing approaches to programming PICs now exists, from high level, iconic, software environments running on a PC to small handheld programmers and even the use of mobile phones. When programmed using high level software, programs can be simulated and validated within the software environment before being committed to the PIC. The PICs in use in schools can be reprogrammed many times and, in some of the available approaches, they can be programmed while they remain in the circuit they are controlling.

  In an electronic circuit a PIC replaces all of the ‘processing’ elements of the circuit; all that is required in the circuit is provision for input and output signals to be connected to the chip and powered appropriately. Thus the resulting circuits are compact.

  Not only do PICs allow pupils to work in contemporary ways with electronics, they eliminate many of the things that are obstacles to pupils’ success in component based electronics; complex PCBs that are difficult to trace faults on, the need to understand a wide range of components, the increasing cost of a circuit as operational complexity rises.

Here are two new e-learning technologies that have rather different emphases but that are both contributing to new approaches to electronics teaching in which electronics design is moving from the physical to the ‘virtual’ realm.

We have established two sets of questions that can be asked of these e-learning technologies, one set relating to their possible economic, technical and social impacts and a second set relating to the way they might support learning. The table summarises, very briefly, some possible responses to these questions.

<table>
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<tr>
<th>Impacts</th>
<th>Costs of software and supporting hardware. Could be disparity in access to the technology. Possible economic impact of greater numbers of pupils leaving school with an interest in electronics design and manufacture. But also an issue of whether the skills gained through new approaches provide a suitable foundation for progression in the subject.</th>
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<td>Technical</td>
<td>Generally shifts the technical demand from lower to higher levels in the system. E.g. with PICS there is a move from a design focus on the operation of individual components to a focus on how the system as a whole should operate. Less focus on handling individual components could reduce confidence in practical aspects of the subject while increasing overall confidence in ability to ‘do’ the subject. Effect on confidence if infrastructure failures leave pupils’ work irretrievable. Confidence in the software is highly dependent on the simulation provided being an accurate simulation of the physical entity.</td>
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<tr>
<td>Social</td>
<td>Greater numbers of pupils engaging with the subject leading to electronics developing a different social image. Technical development is pushing change in examination specifications. Greater success with electronics leading to higher self esteem growing out of mastery of a ‘difficult’ subject. Understanding of the scope of what electronics can achieve more widespread socially leading to greater demands for useful devices. Reduced ability to mend own products due to lack of practical skills – or raised ability to mend own products due to greater confidence in understanding how electronic devices work.</td>
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**Quality of learning supported**

| Support of learning through concrete experience? | Experience is not of concrete objects in the physical sense, but the manipulation of circuit symbols or program elements is a concrete experience that provides concrete feedback. Pupils have the freedom to try out their own designs with instant response from the simulation and no risk of damage to anything in the physical world. |
| Encouragement of active engagement with the subject matter? | The simulation environments have been designed to encourage active engagement with the subject matter, not least because designs can be instantly tested and refined. |
| Support for the elicitation of prior understandings? | The software environments have been designed so that scenarios can be pre-designed by the teacher; these can be used for elicitation purposes. |
| Allowance for progression that is non-sequential? | There is no model of progression built into the software; the approach to progression is dependent on the teacher. |
| Allowance for work in a range of contexts? | Design can be undertaken in any relevant context, but work is always contained in a software environment. Experience with real components is probably required to broaden the contextual experience. |
| Support for metacognitive activity? | Not explicitly built in, but the environments are ripe for teacher metacognitive intervention. |
| Provision of opportunities for pupils to ‘talk’? | Not explicitly built in, but the environments are sufficiently rich that pupil talk will be supported by the environment if encouraged by the teacher. |
On the above analysis, these environments seem to generally pass the learning tests set up and the potential impacts identified are generally benign or manageable. On the basis of this analysis it would be reasonable to recommend this form of e-learning to teachers. But teachers of electronics have, of course, already recognised the pedagogic quality of these new approaches to teaching electronics, if only intuitively; simulation software and PICs are already an ICT success in D&T departments.

Which leaves us with the lesson that, whatever analyses are done on e-learning effectiveness, the voice and the choice of the teacher needs to carry significant weight in funding decisions that relate to e-learning. Teachers, after all, generally really do know best.