A short history off-line

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1 Introduction

1.1 National Archive of Educational Computing

The development of educational computing in the UK began at the moment it was realised that the computer offered a context for learning, and pioneers were exploring its educational use from as early as 1963 (Excell, 1993). Over the years this has resulted in the creation of a wealth of knowledge, experience and artefacts, based largely on investment from the government.

Starting in the early nineties, Ultralab, the learning technology research centre (Millwood, 2006), gathered a large collection of software, hardware and documents. Since Ultralab closed in 2006 this material has been in the care of Core Education UK (Millwood, 2009a) and is being developed to become the National Archive of Educational Computing (Millwood, 2009b). Many other individuals have also saved important material and would like to inform future generations by donating it to a secure and sustainable archive.

The aim of the National Archive of Educational Computing is to look at these materials and to represent them as an accessible and substantially complete collection of one nation’s pioneering and world-renowned innovation. No existing archive, library or museum has an adequate representation of this material and more importantly, very little in the way of narrative, interpretation or analysis is available to the interested public, the education professional or the policymaker. The fear is that in the headlong rush of technological development, the UK has forgotten earlier lessons that may inform its future decisions.

1.2 Computers, software, papers and strategies

The first reaction from most onlookers is to think of a computer museum, but this is already actively pursued by the National Museum of Computing (The National Museum of Computing, 2009) based at Bletchley Park and by the Computer Conservation Society (Computer Conservation Society, 2009), a specialist group of the British Computer Society.

The story that needs to be told is of human creative endeavour, educational practice and government policy. It is these which have formed a social and cultural context for the use of computers in education and which shape the design and developments to come. The design and use of software in particular has influenced educational thinking in flurries of enthusiastic teacher-led development. The influence of curriculum development more widely has also been a key factor in this story – curriculum development in response to the changes occurring in the world of work and the disciplines of academia, changes which in turn have been brought about by new powers to process data, model phenomena and communicate ideas using computers. More recently the internet has, like a benevolent fungus, invaded every sector of human society and mushroomed in significance as the prime focus of knowledge acquisition and sharing, and as the context for social engagement. The challenges faced by education are thus framed by social change as much as technology development. Human society continues an evolutionary symbiosis with its own invented tools which started in the Stone Age. Tools affect our societal development and intellectual progress which in turn affect the development of further new tools (Owers, 2009). The computer presents a new dimension to this symbiosis, providing a new platform for further tool development in much the same way as the invention of the mill-engine or electricity.

So this story is about more than equipment, it is about the software developed to exploit its power, the practice honed to create new teaching and learning approaches and the research, development and theories which have given rise to a strategic response in education from school, local authority and government. Behind the scenes, the technology industry itself jostles to find the most appropriate response to the needs of learners through the creation of new markets, standards and services – and thus has its own story to tell.

Software has been the clay which permits the formation of new resources, processes and communications in learning and teaching. Over the years there has been a keen interest in control technology, which means there are kits for learners to create hardware with to solve simple problems, often in conjunction with programming tasks. The first and most prominent of these was the Logo computer language and its accomplice, the turtle.

Such developments as Beginners All-purpose Symbolic Interaction Code (BASIC) allowed teachers and pupils to create their own programs to solve problems, play games and explore simulations. A wealth of such programs were written in the eighties in particular to meet the needs of enthusiast teachers.

In some cases, such software was developed by large-scale curriculum development projects underpinned by early ideas of standards and interoperability. In such cases, software was trialled in classrooms and improved on the basis of feedback before an alliance formed with publishers resulted in wide dissemination.

Over the last thirty years it has been interesting to observe the focus for leadership – at times from isolated innovative practitioners, later from curriculum development and research projects alongside local authority advisors and private consultants in small firms, and latterly, from the large firms which have arisen as government investment has increased. As the Web 2.0 phenomenon has arisen in the last five years, innovative practitioners are again able to share, but now at low cost and ever greater reach, and critically reflect with others on the approaches taken. The UK story is marked by considerable individual autonomy with regard to curriculum approach in the early years (1960s to the 1980s), leading to effective and inventive response to the new tool. Unfortunately, in the last twenty years curriculum constraint has tended to restrict teachers' creativity and has led to a reactionary force of using the computer to support traditional teaching in the main. This can be seen most effectively by the way in which the interactive whiteboard, an electronic chalk board, has developed as the focus for much investment in this decade. These have been used by some teachers simply to support existing practices. This idea was first proposed in the late seventies by the Investigations into Teaching with a Microcomputer as an Aid project (ITMA) (Phillips, Burkhardt, Coupland, Fraser, Pimm and Ridgway, 1984). Software to support such a role for the computer was developed with careful curriculum design and research. At the time it was an imperative to maximise the effectiveness of the single computer in a school, let alone a class, and thus was an appropriate course of action. Now that one-to-one (computers to pupils) has become a real possibility, it is surprising to see such emphasis on the teacher as 'sage on the stage', but shows how we regress in the face of the unknown to our simplest ideas of teaching and learning.

As interest has grown in development and creativity, so has educational research sought to make sense of the changes in education. The wealth of new books and papers driven by conferences and research funding has been enormous. The field has been challenged by the pace of technological change, leading to a situation where it is often unclear whether research findings in the context of one set of technology can be applied in another. The National Archive of Educational Computing will make an attempt to unpick this and recognise the work which has endured, and thus may be useful as a guide to future action.

Thus throughout this short history, the education system has sought vision, clarity and simplicity in a context where few question whether we should use technology, but many are uncertain about how it should be deployed, in the face of such a flexible but expensive tool. It is no wonder that strategy documents abound and a major part of the National Archive of Educational Computing's unrealised wealth will come from re-presenting earlier strategic visions and contrasting them with the reality.

2 Before microcomputers

2.1 The teletype

1970-
1979

In the seventies, the subject of computer studies was gaining ground and was often taught by mathematics teachers. The subject was a dry exposition of the structure of a computer, the code which it stored and the algorithms which drove it. This was augmented with ‘applications’ – the use of computers in the public service and commercial worlds. There was curiously little about the military applications which arguably drove the whole industry forward. Practical work at its minimum meant drawing flow charts, marking or punching 80-column cards or punching paper type. The time between expressing your ideas as a program and seeing the results could be as long as a week. Some local authorities and colleges pushed this further than others and in some schools a teletype was made available along with a dedicated telephone line to connect to a local university, polytechnic or council ‘mainframe’ computer. This was ‘real-time’ computing, in that programs could be entered and results obtained within seconds, albeit printed at 10 characters per second (an A4 page of text would take approximately five minutes to print). Word processing and spreadsheets had not been invented, emails just begun.

Cutting-edge work here included using science simulations – for example, learners typed values for variables and waited to see what would happen to an imagined test tube and its chemical reaction. Such was the scarcity and value of this computer time that curriculum development focused on science beyond the reach of the school or university laboratory.

Creativity
Much of the creativity in this era centred on programming and pedagogy. Learners’ access to creative tools was limited even in the now familiar worlds of writing and document production. Some enthusiasts constructed DIY and kit computers and applied them creatively to problems as a means to understand the technology. Teachers developed methods of using exploratory simulations, making expensive experiments cheap to run.

Communication
Email was still new and it was rare even for the computer to be used in front of a whole class to present ideas. Communication took place around the computer, rather than through it.

2.2 Graphic displays

In the late seventies, microcomputers were invented, notably the Research Machines family, the Apple II and the Commodore Pet. At first these offered ‘glass teletype’ screens which although on a television style ‘monitor’, emulated the print-out of the teletype. Soon the opportunity to use graphics and thus visualisations was seized on and exploited to make engaging and delightful programs for learning. Such was the enthusiasm generated that some teachers bought and built computer kits to take part in what was a revolution in affordability. The possibilities provided a foundation for one of the most creative periods in the development of interactive audio-visual materials underpinned by explanatory and enlightening mathematical models, substantial and persuasive data sets and the realisation of the computer as a tool in learning and teaching. Thus began the era of computer-aided learning or ‘CAL’.

2.3 Evaluation

One of the earliest government initiatives of this era was the National Development Programme in Computer Assisted Learning, reported on by its director, Richard Hooper (Hooper, 1977). A programme aimed at the higher education sector, it explored the range of possibilities that early computing power offered in a university setting. Its most potent outcome came from its evaluation study undertaken by the Centre for Action Research in Education at the University of East Anglia (MacDonald, Atkin, Jenkins and Kemmis, 1977). The analysis is based on:

> ... three paradigms of education through which we may grasp the major ways in which developers of computer assisted learning conceive the curriculum task. We have called these paradigms the 'instructional', the 'revelatory', and the 'conjectural' ... they are our 'inventions', intended to help the reader to relate CAL to the general field of educational theory and practice.

MacDonald *et al*. explain that the theory behind the instructional paradigm is derived from Skinner's work, and is based on the belief that pupils may acquire knowledge through transmission and reception of verbal messages. The revelatory paradigm is theoretically related to work by Bruner and Ausubel in which knowledge is acquired through the gradual revealing of concepts in the subject discipline. The conjectural paradigm is related to the theories of both Piaget and Popper and views knowledge as evolving through experience. Some of the main features of these paradigms are summarised in the following table.

Educational Paradigms for Computer Assisted Learning (MacDonald, Atkin, Jenkins and Kemmis 1977)			
	INSTRUCTIONAL	**REVELATORY**	**CONJECTURAL**
Key concept:	Mastery of content.	Articulation and manipulation of ideas and hypothesis-testing.	Discovery, intuition, getting a 'feel' for ideas in the field etc.
Curriculum emphasis:	Subject matter as the object of learning.	Understanding, 'active' knowledge.	The student as the subject of education.
Educational means:	Rationalisation of instruction, especially in terms of sequencing presentation and feedback reinforcement.	Manipulation of student inputs, finding metaphors and model building.	Provision of opportunities for discovery and vicarious experience.
Role of computer:	Presentation of content, task prescription, student motivation through fast feedback.	Manipulable space/field/'scratch pad'/language, for creating or articulating models, programs, plans or conceptual structures.	Simulation or information handling.
Assumptions:	Conventional body of subject matter with articulated structure; articulated hierarchy of tasks, behaviouristic learning theory.	Problem-oriented theory of knowledge, general cognitive theory.	(Hidden) model of significant concepts and knowledge structure; theory of learning by discovery.
Idealisation / Caricature:	At best, the computer is seen as a patient tutor; at worst it is seen as a page turner.	At best, the computer is seen as a tool or educational medium (in the sense of milieu, not communications medium); at worst, as an expensive toy.	At best, the computer is seen as creating a rich learning environment; at worst, it makes a 'black box' of the significant learnings.

MacDonald *et al*. continue their analysis by pointing out that a useful distinction may be made between authentic and inauthentic labour by pupils and teachers. Authentic labour is that which is directly concerned with valued learning; inauthentic labour may be instrumental to valued learning but is not valued in its own right. They continue:

> The computer is peculiarly suited to reducing the amount of inauthentic

> student labour, however, and many CAL applications exploit the information handling capacities of the computer to improve the quality of the learning experience by taking the tedium out of some kinds of task.

This leads to the idea of a fourth paradigm, the emancipatory paradigm, in which the key concept is the reduction of inauthentic labour, but this does not occur in isolation to the three paradigms initially defined, since each reduces such labour to some extent.

This analysis was the basis for much clarity of explanation throughout the following two decades, but is not often employed today, despite its useful distinctions and rich link with theoretical views of learning.

3 Before office productivity tools

3.1 Studying the computer and microelectronics

1980-1989

At then end of the decade, institutions across the UK began to take notice. In 1979, the outgoing Labour government voted had planned for a major investment in schools and this plan was carried out by the incoming Conservative government. In the entrepreneurial science parks of Oxford and Cambridge, new companies emerged to build the microcomputers demanded by society, commerce and education, leading to the establishment of Research Machines, Acorn and Sinclair. At the same time, the Continuing Education Department at the BBC noted the rise of the microcomputer as a pervasive influence on society and began to propose a national campaign, which eventually became known as the BBC Computer Literacy Project, launched in 1982. The government investment of £12.4M by the then Department of Education and Science (DES) became known as the Microelectronics Education Programme (MEP), led by the late Richard Fothergill who developed a strategy which seems timeless in its values and ideas (Fothergill, 1981).

In devising MEP's aim in April 1981, Richard Fothergill forecast accurately:

> "The aim of the Programme is to help schools to prepare children for life in a society in which devices and systems based on microelectronics are commonplace and pervasive. These technologies are likely to alter the relationships between one individual and another and between individuals and their work; and people will need to be aware that the speed of change is accelerating and that their future careers may well include many retraining stages as they adjust to new technological developments."

He also made the following assumptions clear:

> "In developing a strategy for the Programme it has been assumed that:
> i) schools should be encouraged to respond to these changes by amending the content and approach of individual subjects in the curriculum and, in some cases, by developing new topics;
> ii) with the dual aim of enriching the study of individual subjects and of familiarising pupils with the use of the microcomputer itself, methods of teaching and learning should make use of the microcomputer and other equipment using microprocessors. This may be expected to add new and rewarding dimensions to the relationship between teacher and class or teacher and pupil;
> iii) use should be made of the microcomputer to develop the individual pupil's capacity for independent learning and information retrieval;
> iv) for those children with physical handicaps, new devices should be used to help them to adjust to their environment while those with mental

handicaps should be encouraged and supported by computer programs and other learning systems which make use of the new technologies."

Investment in computers was supported by the Department of Trade and Industry's (DTI) Micros in School Scheme, providing 50 per cent of the funding from central government for each school to buy one computer. The deal obliged the school to take up two days of in-service training so that staff might know what to do with the new tool.

It is a measure of how hard it is to shift the 'culture of schooling' that even now, thirty years later, relatively modest transformation has occurred.

In spite of Fothergill's aim, the curriculum and assessment at this time was directed at computer studies, which entailed learning the underpinning theory of computers and testing this knowledge in paper examinations. The study of the computer itself and the nature of microelectronics remained dominant, since office applications were immature, digital media non-existent and internet the province of higher education at best.

Creativity
More accessible forms of programming allowed young learners to develop their own ideas and express conceptual thinking with aesthetically delightful drawings through the Logo turtle's pen. The first word processors and painting programs, made widely accessible through microcomputers, encouraged new artistic activity. Computer games brought arcade-style action into the home.

Communication
Email developed rapidly and bulletin boards became popular – islands of online community connected people through 'dial-up'. Publishing through teletext and Prestel seeded ideas of the web to come.

3.2 Creativity and problem solving

The first signs of a use for the computer that was wholly focused on learning itself, came from the work of Seymour Papert and colleagues with the invention of Logo (Papert, 1980). This programming language was designed to foster creativity and problem solving, and with its concrete 'object to think with', the turtle, enthused teachers and learners to engage with the computer in an entirely new way. The body-centred geometry of the turtle inspired exploration, fun and artistic meaning and many viewed it as an emancipation. Constructivist theories of learning became practical, and practitioner conferences were held. Other programming languages were exploited, invented and disputed, including BASIC, Prolog, Comal, Pascal and even Lisp, but none captured the imagination as powerfully as Logo.

A Logo example:

```
TO TRIANGLE
REPEAT 3 [ FORWARD 100 RIGHT 120 ]
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This procedure commanded the turtle to move along the edge of an equilateral triangle, 100 units along each side. The mathematics of the triangle are captured in the Logo procedure, and it is a basis for a procedure for drawing a polygon with many sides.

What happened to this promising dawn? Eventually such creativity and problem-solving activity could not be attached to an increasingly vocational focus based on the rise of the computer as an office necessity. ‘Real’ problems were not readily solved, and more vitally, many learners did not benefit from the logical, procedural and mathematical approach – Logo suited those who naturally found pleasure in tackling such problems and relished the debugging of sometimes obscure errors.

3.3 Simulations and games

The new BBC Computer Literacy project aimed to open up computing and microelectronics to a wider public, anticipating that programming would become a new literacy. The specially commissioned BBC computer, manufactured by Acorn, included a mature and expressive version of the BASIC computer language. This lowered the threshold for would-be programmers, and a raft of magazines published computer programs for enthusiasts to type into their home computer, and save onto audio cassette for re-loading later.

This was clear encouragement to teachers in all sectors to create their own computer software. Some innovative teachers went on to found companies, and a few still trade even now. Small games for simple conceptual development were swapped and self-published, some becoming classics.

3.4 The applications approach

Towards the end of the eighties the commercial and domestic markets for microcomputers were beginning to mature. The *Office* suite of software was dominant and became the basis for the curriculum. Arguments against learning-specific software (not ‘real world’) and the more generally applicable office software (an entitlement) were supported by the rise of a National Curriculum in which technology was embedded and used in all subjects. Word processing, spreadsheets and database software were enough to support every curricular need for productivity in text, numbers and information handling. Specific simulations, creativity and problem solving took a back seat – awaiting the invention of yet another wave of creative technology.

4 Before the internet

4.1 Interactive multimedia

1990-
1999

In the eighties, the predominant method of distributing data was the magnetic ‘floppy’ disc, but a new way to distribute media in the form of the laser disc began to take hold. Early examples included the Domesday Disc (Millwood, The Domesday Project, 2009) produced by the BBC to celebrate the 900th anniversary of the Normans’ *Domesday Book*. Like its predecessor, it attempted to portray and map the UK through video, pictures and text, some taking a national perspective and others collected by schools and others to cover each 1km square of the National Grid. Added to this rich descriptive material, was data sourced from the Birkbeck College Department of Geography, the Centre for Urban and Regional Development Studies at the University of Newcastle, the Economic and Social Research Council Data Archive at Essex University and the Institute of Terrestrial Ecology, Bangor. This interactive multimedia resource anticipated the rise of the compact disc (CD-ROM) by combining media and data in a remarkable, interactive and revelatory manner.

Creativity
Attention shifts from the computer to its applications. Desktop publishing arrives, digital photography, filming and music production all make an impact as multimedia and hypertext offer new combinations with interactivity to bind them together.

Communication
The ‘C’ in ICT arrives with the internet. Web publishing and content management systems seduce many to believe ‘content is king’, but the online communities emerging show the way forward at the end of the millennium. Learners have growing access to a wealth of information, people and media.

New tools for authoring such material had arisen in the late eighties, such as HyperCard, ToolBook and Director. Adobe Director still survives, though Flash now dominates the field. These tools reduced the cost of authoring complex information, including photographs and audio, to such an extent that a new generation of authors was empowered to create rich learning materials. Although the costs of reproduction and distribution were initially high, the technology improved so far that the costs of ‘cottage industry’ levels of production were reduced to a few pence per copy. Initially, video took a step backwards, reduced to postage stamp size and poor frame rates, but as technology continued to obey Moore’s law, full-screen video at full frame rate became achievable.

4.2 Digital creativity

As the tools for designing interactivity and production blossomed, so did the equipment for capturing rich media. The digital camera began to lower the cost of originating images as software to post-process permitted imaginative editing. The scanning equipment which the print studio used to capture paper materials became ever smaller and cheaper. Finally, the video camera, despite using magnetic tape for recording, moved beyond the splicing of tape to a digital-domain editing technology, permitting a provisionality of use only experienced in the text and graphics world of computers so far.

Such changes offered the author, often a practising teacher, substantial opportunity to create content, but as technical improvements brought costs down, increasingly education could afford to use the tools for expressive purposes. Thus was born the modern concept of digital creativity, where children took on photography and film-making challenges within normal classroom constraints with ambition that boggled the mind of professional camera operators and film editors.

Arguably these developments are significant to learning, providing diversity of content to widen access, but more importantly to offer a broader range of learning styles through creative project work. The effects on traditional systems of assessment are still being felt.

4.3 Bulletin boards

Email predates the internet, offered to groups of users using systems such as British Telecom Gold or Applelink. These systems required the user to connect to a particular server computer using the telephone network. The difficulty with using email in managing knowledge within an interest group led to the development of bulletin board systems. These systems made it possible to take part in whole group conversations by writing messages and responding in a forum, where messages were visible to members, new and old. This meant that a newcomer could take the trouble to read the past conversation before taking part, thus benefiting from the information already shared and avoiding the ‘sin’ of repeating an argument.

A few pioneers saw immediate value in using such technology in education to promote a more global outlook, to benefit from expertise and to engage in joint projects. One such venture, Project Ebenezer, linked the pupils of schools in Letchworth, Hertfordshire. Its activities included business simulation tasks conducted over extended periods and its effects included a change in the relationship between pupils from different schools, reducing enmity and promoting collaboration.

By the middle nineties, pioneers began to use such tools as a substitute for the classroom to run undergraduate courses (Open University – Gary Alexander), introducing a new era where technology’s value was in its promotion of communication between learners, leading to a change in acronym from IT to ICT in the late nineties.

4.4 Cross-curricular

Early uses of the computer in education focused on understanding the technology and its roots or in specific subject disciplinary topics, but as the computer began to grow in its range of applications its use spread to all subjects. This led many to view ICT not as a subject in itself, but as a utility in the practice of teaching and learning. The application of hypertext as a linkage between media allowed holistic, cross-curricular content to be designed by publishers and teachers and form the basis of pupils' project work. Over the 1990s the subject of Computer Studies sank without trace. University Computer Science departments invited students to focus on mathematics and this accelerated the decline. Eventually, educators could see that the functional skills of operating computers and software could be taught across the curriculum without the need for a specialist school subject. All would be well with this approach if it had also dealt with the conceptual knowledge that surrounds computers, their operation and underpinning principles, which for many could be airily dismissed as 'under the hood', and thus not important. The effects of such an attitude, seen many times before in the context of some of the most critical intellectual endeavours (engineering, manufacturing, trade) may still rebound on us.

5 Before the cloud

5.1 Content and the dot.com bubble

2000-2009

The mid nineties saw the rise of the internet – an architecture for information to be routed throughout the globe and into the home, and subsequently into the pocket. It started with the desire to share and publish information, so organisations set up servers and published content, leading to the woefully limiting catchphrase ‘content is king’. The more ‘authoritative’ and unique the website, the more valuable it was conceived to be, and the greater the opportunity to ‘monetise’. Such was the hype, that in the late nineties a worldwide bubble of ‘dot.com’ companies arose and then crashed, as it was discovered that authority itself was under challenge. The immediacy and power of the world-wide web began to reveal the inadequacies of old power-structures in publishing and in news, resulting in the phenomenon of individual blogs and the emergence of collaborative wikis. Many of the social structures that had been experimental in earlier decades became real – social networking had arrived.

All this had its effect on education, but the greatest developments have come not in mainstream formal schooling, but in the informal spaces which have given access to new responsibilities which know no age-boundary.

Creativity
Online services offer sharing of media, web page development and construction of the personal identity. Teenagers decorate their online spaces like their bedroom, but to a global audience. Digital creativity arrives in the way that desktop publishing did a decade before to empower diverse learners’ expressive preferences.

Communication
Communication becomes pervasive with ubiquitous mobile telephony and a focus on social networking. Learners can engage with others, able to discover when, where, what and why with the touch of a button, wherever they are. Technology supports learning dialogue distributed yet located in time and space, and new forms of presence, in virtual worlds, become possible.

Two of these developments – MySpace and Wikipedia – represent two different ends of the same phenomenon. MySpace has given anarchic, taboo-breaking creative power to many thousands of young people sharing ideas, media and conversation. Its outcomes are as a vent for the latent creativity in all people. Wikipedia, on the other hand, is a search for truth, a space for serious debate, a focus for agreement and for dissent. Its power in recent years to dominate the world of reference material and put to an end some of the most powerfully sponsored authoritative sources, such as the recently closed Microsoft Encarta (62,000 articles according to Wikipedia), shows what a shift Wikipedia represents (6 million articles according to Encarta, 13 million according to Wikipedia).

Just as significant is the development of YouTube, the contributory repository for video material, which for some is a first port of call to search for new knowledge.

5.2 The e-institution

While the rise of informal learning through the internet enables individuals to achieve, it is less clear that it facilitates society's needs. The erection, funding and quality assurance of educational institutions has been undertaken to mass-produce the educated individual according to a pattern that society has determined it needs to sustain itself. The ability to select candidates for job interviews cost-effectively is one driver for qualifications and thus examinations. More generally society attempts to be meritocratic and find leaders who are its best educated and highest achievers. Examinations are thus a 'gold standard' and are not readily innovated to accommodate the self-directed, multi-modal, creative informal learner that the technology has facilitated. This clash of cultures may help explain the failure of e-institutions such as the UK eUniversity or the National Health Service University, both casualties in the 'noughties'. The design of e-institutions needs invention and responsiveness without sacrificing rigour and confidence – tradition will simply not do.

The emergence of the 'cloud' – using distributed server 'farms' to store information and organise services based on individual identities and online communities – promises much for such a re-design, one that recognises a citizen-centred approach to education and delivers a lifelong utility to society.

6 Before the future

6.1 Successes

In anticipating future developments, what certainties for success can we identify? These depend on analysis of new technologies' likely affordances, but are more importantly based on a clarity of human needs that are unchanging – part of the human condition and which have been seen to influence success and failures in the past. I have chosen three:

2010-2099

6.1.1 Access to learning

My certainty here is that new technologies must widen access to knowledge, both in its creation and in its use, to promote informal learning. Limiting access in time, pace, modality and place only serves the minority favoured in such discrimination. Interestingly, as our society has shifted, ease of access has been redefined by extended opening hours, communications systems as infrastructure rather than service, new conceptions of abilities rather than disabilities, and cultural diversity rather than purity. Once the public library as a stuffy, quiet institution would be seen as serving this need, but it is now reinventing itself to be lively, dynamic and open.

Creativity
New conceptions of media and genre become democratically available to offer fertile ground to all learners willing to express creativity – the challenges are all about assessment, fairness and digital equity.

Communication
As with creativity, inventive and ingenious ways to communicate so that we may test ideas and access formative assessment and expertise are easier to use and thus can enhance learning, if only we can develop the necessary skills and avoid the debilitating barriers of the 'gold standards' in education. Fear of abuse is driven by the amplification and reach of our capacity to communicate.

6.1.2 Richer and more extensive content

This certainty is informed by the success of digital creativity in enriching content and its value and should not be confused with the publishing industry alone. Technologies now must permit rich media both in delivery and creation in order to offer a wealth of creative opportunity to the multimodal learner. Where there is still room for development is in the creation of new and powerful juxtapositions of media and the tools to cheaply create them. One very obvious omission is the multiple sub-titling of video material, a technology which can allow the micro-referencing, labelling and annotation of video available to all. YouTube is just beginning this adventure, but the challenge is not to do with technology alone. Apple's QuickTime has offered this capability for over fifteen years, but must break the conception of video as a broadcast, narrative medium before it is of any use.

6.1.3 Communications and social networking

This is the easiest of the certainties to defend – few would argue that language, communication and social power are the very stuff of human existence. Unfortunately our conception of these is often limited in the software environments which are available to us in an online world. The big successes have come where individuals as social engineers can represent their identity, characterise their interests and experience, demonstrate relationships and form sub-groups to organise life. Hence Facebook and Twitter continue to grow despite the rearguard critique from the 20th century. The automated gossip of Facebook and the human chatter of Twitter are key to their success.

6.2 Failures

What could possibly go wrong? Again I offer three failures:

6.2.1 Industry/Education divide

The continuing failure to recognise the anti-industry prejudice in our society and its knock-on effect in education has often been seen in the context of technology in education. It is paralleled by an anti-education prejudice that can limit the opportunity for teachers to exercise their professional creativity as a response to technology innovations. New technologies need to acknowledge this background to their introduction in education and be inventive in order to overcome barriers.

6.2.2 Misunderstanding the human–tool symbiosis – “it’s just another tool”

In the discourse that surrounds the computer, this dismissal is often heard, arguing that we should start with learning and then apply technology to solve the problems encountered. The missed opportunity here is huge, owing to a denial that working, living and learning may be quite different experiences due to the symbiosis we experience with tools based on technology. New developments may well change human performance and then our learning environments, curriculum and assessments are all called into question.

6.2.3 More of the same – productivity without transformation

This failure has plagued education since the first application of technology to learning. I mean of course the building of teaching factories and the continuing confusing between these and *learning communities*. Throughout the history of computers in education we see outbreaks of productivity solutions for mass-teaching. They will fail us unless we appreciate the need for transformation.

6.3 Constants

Of course, the history of computers in education is made by those in various levels of power – the politicians, educationalists, researchers and teachers. Their inventions, analyses and practices tend to be system-, institution- and teacher-centred as a result, it’s only natural. But their task is to serve the lifelong learner and it will be re-interpreted according to the scope of their analysis and the technologies of the day.

A way to cut through the historical variety that can obscure wisdom, is to construct analyses which stand the test of time – the NDPCAL instructional/revelatory/conjectural/emancipatory analysis in relation to the role of the computer for the learner seems to be such and I find it useful to this day when analysing new approaches. But in order to take a more holistic approach, I propose a focus on an imagined learner's concerns. Few real learners will articulate such concerns in the form of questions, partly because we usually do not ask them to participate in such issues, but by posing these questions as 'constants' we may test future proposals more effectively than starting from the status quo of a current or historical solution. In this diagram, (Millwood, TeachMeet 09 - The Learner at the Centre, 2009), the learner is imagined to be concerned with eight questions, relating to eight areas that an innovator should consider if they wish to make an impact on learning with an invention in technology or practice.

But the issues at the bottom of the diagram – responsibilities and rights – are at the heart of the modern dynamic that education and technology present. Learners' entitlement to access knowledge was at the heart of the development of the National Curriculum, but we must add to that the entitlement to opportunities for access, creativity and communication and the responsibilities that a free and open education brings.

Re-inventing education is a hard task, but I hope that this analysis, backed up with case study and evidence from the historical record, can act as a compass in the very turbulent knowledge society that new technologies have engendered.

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