IT Trends and GIS Education and Training - A White Paper

James R. Petch
Manchester Metropolitan University, UK

1. Introduction

The purpose of the White Paper is to support a wide ranging discussion on the future of GI Education and Training and in particular to focus on those elements of change which are likely to be driven by or linked to changes in information technologies. This is regarded by the author as perhaps the greatest challenge to education worldwide at the current time.

The paper has three parts, a review of technology trends, an analysis of the business issues related to these trends and a brief exploration of the possible impacts on the GI education. The term business is used here in the widest sense to include commercial organisations, government organisations, public bodies and so on.

In preparing this paper an assumption which had to be discarded was that the consideration of the changing environments of education and of business could be treated separately. This proved impossible and came to be seen as pointless. GI education and training are just another part of the business melting pot. They are subject to the same forces and have to address the same issues. And so in the analysis which follows the discussion moves seamlessly from business to GI education and training. Only in the third section is there a separation and the specific context of education is considered. Here, although GI education and training provision are mentioned, most if not all of the points apply across the education sector.

A further assumption of this paper is the coupling of GI education and training with business needs. This is not to ignore the 'discipline' or 'field of study' of GI, which may not have any specific business related objectives, but is a useful way to focus on common issues without getting side tracked in academic arguments. It is believed that much of what drives academic GI education is business related and reflects the close links that exist between many GI educators and business.

2. Views on Technology Trends

Nowadays, it is not possible to provide a fully up-to-date and comprehensive review of changes in information technology. The field if it can be called a single field, is far too complex, pervasive and dynamic to describe in a single paper. Here an attempt is made only to cover what some experts believe to be the main changes and to consider them at a high level. This is based on the 1999 (already dated) review of the UK ITEC Technology Group (ITEC, 1999). The ITEC Technology Group Forward Look Paper (March, 1999) takes a layered approach to its analysis of technology trends. Its levels 0 – 3 provide a basis for speculating on the capacities of systems both for GIS processing and for education delivery.

Level 0 Technologies are the basic technologies of transmission, of storage and of materials used in computing.

Level 1 Technologies are at systems level and relate to capacities of systems.

Level 2 Technologies are the supporting software technologies and management methods for applications.

Level 3 Technologies are at the applications level and here are focused on generic elements of applications.

3. Level 0 Technologies

3.1 Transmission

There is a shift from wired to wireless transmission which is accelerating. Medium rates (6 Mbytes/s) are achievable with ADSL but using the Internet 2 Mbytes/1 are likely. High transmission rates are achievable over wired systems but only over short distances. Fibre optics are required but bottlenecks will remain. VSDL technologies will allow up to 25 Mbytes/s downstream bandwidth. Developments is cellular telephones will now allow up to 2 Mbytes/s with mobile broadband systems allowing over 2 Mbytes/s after about 2008. Second generation systems allowing multimedia are expected from 2002-2007.

Digital satellite systems will be available to the home from both fixed and mobile platforms. These will have sufficient bandwidth for multimedia if bands can be allocated. Fibre technologies offer almost limitless capacity but limits are provided by electronic interfaces and equipment. Availability of multiple wavelengths promise networks with 64 or 128 terminals each having 1Gbyte/s connection to every other terminal. These ultra high capacity optically re-configurable transport networks are now emerging.

A key issue will be seamless roaming. Software radio with wearable and disposable radios could have a big impact. By 2010 it should be possible to have sensing and thinking terminals as personal assistants. If software is developed there could emerge important person-centred applications.

Some Likely Timings

Low earth orbit satellite communications	2000
No wiring need in home/office computers	2002
Hand held video phone	2000
Multiple channels >100Gbytes on single fibre	2002
10 Mbytes/s to homes common	2001 - 2004
Mobile users have seamless virtual environments	2003 - 2007
Terabits per second on optical fibre over long distances	2004 - 2007
Fixed network phones no longer sold	2005 - 2007

Software radios universal	2008
Software telecommunications networks	2010

3.2 Image Display Technologies

Displays will continue to be dominated by CCD sensor and LCD display (Mobile) technologies for some years. CMOS sensor technology is in its early days but promises cheaper, less power hungry display with random access at pixel level. This could be the basis for intelligent cameras and therefore displays.

Mobile systems will benefit from developments in LCD technology with marginal increase to 1600 x 1200 pixels and 8 bit grey scales. Improvements in power consumption and viewing angle will enhance lap top products. Poly-silicon based products will compete directly with LCD products up to lap top sizes.

CRT will dominate desktop display with resolutions up to 1600 x 1200. Sizes will continue to increase marginally and flat screen products will continue to gain market share. Larger displays will enter the display and advertising markets.

Other developments are taking place with SLM (Spatial Light Modulator) technology for heads up display in vehicles, mirror displays (DLP – Digital Light Processing) technology and flexible displays on plastic screens.

Some Likely Timings

Eyeglass/headings display in mobile computer	1999
Electronic newspapers	2000
Fridge front e-mail on cordless devices	2000
Electronic notebook with contrast as good as paper	2002
Every new car with heads up display	2003
Personal display tablets with resolution as good as paper	2008

3.3 Storage

Memory sizes are forecast to increase dramatically though the effects are reduced by more demanding operating systems and software and by the requirements for real-time response which involves data manipulation directly in memory. Memory capacities have and will continue to double every 18 months for the same price for another 10 years. There will be increased integration of systems even onto single chips. Hard disk costs will continue to fall even as capacities double every 18 months. Dramatic increases in capacity of tape and optical storage will continue. Moves to green and possibly blue lasers will produce capacities of 12 to 20 Gbytes per layer and the limits to transfer rates will be limited to about 30 x CD drives because of drive problems.

Some Likely Timings

1 Gigabyte memory chip	2000
TV's with disk drives	2000 – 2002
Terabyte memory chip	2007 – 2010

3.4 Portable Energy

Breakthroughs in portable energy are slow compared to IT markets. Low power consumption technologies are coming. Nickle Metal Hydride batteries, with higher power and longer life, are becoming available but their cost-effectiveness if not clear.

Lithium polymer materials are being developed but their effect is not clearly established. Solar power is expensive and so far not adopted by manufacturers. Micro-gas turbines may offer an alternative to batteries but the IT future remains unclear.

4. Level 1 Technologies

4.1 Processing

Moores Law will continue to operate. By 2005 high end PCs will execute 10 Gips and have many special accelerators, e.g. for 3D. A wide range of embedded computing will emerge with games, set-top boxes and wearables.

Some Likely Timings

Super computers with speed exceeding 1 TeraFlops	2001 – 2003
Integrated wearable computers	2000 – 2002
Quantum computer	2004 – 2007
Molecular computing	2007 – 2010

4.2 Radio Spectrum

This is a finite resource under great pressure. Most severe problems will be for international applications. Digital TV will release analogue bands in mobile and broadcasting.

A barrier may be international agreements to cope with numbers of satellites, allocation of frequencies and interference problems.

5. Level 2 Technologies

5.1 Image Analysis and Speech Recognition

Image analysis technologies are now sufficiently rapid to allow widespread adoption of techniques established in the 60's to 80's. They are becoming commonplace helped by

compressions techniques and high speed storage. Advances in algorithms are rapid especially based on projective geometry.

Applications in the next 5 years will depend on acceptance rather than technology. These are in areas such as:

- Visual cruise control and intelligent surveillance
- Automated road traffic control
- Gesture driven interfaces
- VR model generation from hand-held video

Other application areas which remain possible within the next 5 years include:

- Very low bandwidth compression for video telephony
- Reliable face recognition
- Content based image retrieval

Speech recognition remains very limited compared to human capabilities and lots of developments are in train which will allow transcription, speech interfaces which will substitute for a mouse and longer command statements.

Some Likely Timings

Complex transactions based on speech recognition	2002
Majority of users talk to computers	2004
Full speech interaction with mobile phones	2005
Babel fish [*]	2007 – 2010

5.2 The Internet

The range of technologies which support internet activities is wide. In each area there are rapid developments and it is difficult to speculate on the time frames for availability and uptake of new products.

For most of these level 2 internet technologies these time frames are short rather than medium term, i.e. before the end of 2002. Some of the key areas are:

- performance control of networks
- multicasting
- routing
- scalable server technology
- wireless and wireless operating systems

[*] from 'Hitch Hikers Guide to the Galaxy' – a babel fish placed in the ear simultaneously translates from all languages to any other. (Note: for non-English humorists – this is English science fiction.)

- interactive TV
- smart spaces
- low cost devices
- virtual environments
- billing
- security
- certification
- WWW/VRML/SMIL/XUL convergence

5.3 Software Engineering Tools

The last five years have seen accelerating developments in customisable packages. These have been based on adoption by vendors of high level distributed computing standards for data access and communication. These standards include www, http/html, OMG, CORBA, DCOM, STEP.

The consequence of this is already becoming apparent as many niche application vendors operating against a backdrop of core standards established by major vendors. The efforts of these vendors are going towards distributed computing. These involve networks of machines, users and applications and involve highly interconnected business systems.

5.4 Programming Technologies

These developments in distributed systems are progressing on the back of developments in object oriented programming. 0 – 0 is the primary focus for new projects with the possibility of having meta-objects, introspection, reflection and dynamic binding which will allow software to inspect and modify itself on the fly. Current languages don't allow these facilities.

Defining rules to allow safe execution of these capabilities is in the research domain. The missing ingredient is the means to manage change without heavyweight overly centralised approaches.

Once solved, this opens up the possibility of developing generic software containers for transaction processing, security, data replication, etc. that can wrap application components with the desired facilities. This will allow software to be tailored to specific environments and open up organisations and their 'legacy' systems to applications of business partners.

5.5 Distributed Processing Environments

The prospects for advancement are being brought about by the convergence of CORBA and Java which will allow use of software components across networks. The impact of this convergence will be significant. Application builder tools, which dominate applications development, will now be able automatically to call up the components they need to support distributed environments, whereas today they are typically locked into a single networking model.

If an application is configured to reflect a changing business environment, alternative components can be substituted transparently, indeed automatically and dynamically in the case of mobile objects such as agents. With the ready availability of middleware components and tools to configure them into applications, then users will become more comfortable with setting up and using distributed environments. This will, in turn, lead to a change from today's 'client-server' environments to distributed computing.

One requirement for distributed computing is standards (TCP, URL's x 500 certificates, SSL, DNS, etc.) becoming universal, though how CORBA/Java and Microsoft (DCOM, Active X) paths will converge is not fully clear.

5.6 Formal Methods

Use of formal methods has long been advocated by academics and some industry leaders have traditions of using them.

In general the take up is sluggish and the application partial, reflecting both a preoccupation with delivery rather than quality and a culture antagonistic to engineering.

There are signs of change as concerns increase about the degree of trust that can be placed on behaviour of software. Some companies report impressive reductions in software error rates with adoption of formal methods. However, the whole area is complex and presents a confusing picture to new entrants.

5.7 Security

The main driver for security is internet applications in e-commerce. Security is implemented at different levels and include encryption and authentification and the secure protocols which makes use of the cryptographic algorithms and the means to implement them on a variety of platforms. Also, there is now a basic understanding of how to integrate these techniques into secure distributed applications. However, there is a limited mathematical basis for, encryption and advances in mathematics could undermine the effectiveness of security algorithms leaving systems designers with no obvious alternatives.

The biggest area of concern is the management of secure systems including the design and operation of the PKI (Public Key Infrastructure) needed to underpin the use of digital signatures in e-commerce. The questions which remain are about the emergence of dominant PKI's, either globally or within application domains, and the issue of liability. These two issues will control speed of roll-out and cost of e-commerce systems.

6. Level 3 Technologies

6.1 Distributed Virtual Environments

These will be widely used for remote collaboration and social interaction but there remain many technical, design, and social challenges. In progressing the technology there is a fundamental trade-off between scale, consistency and complexity. Multi-user "shoot 'em up" games will be the lead commercial application with the key requirements being consistency between players.

For business, scale might be the key issue, with increase with power and network bandwidth then overall performance of DVE's will improve. However, the need for application specific compromises will remain if only because of the demands on processor and network resources which are radically different from passive broadcasting or asynchronous applications.

Some DVE's need to be created each time they are used but increasingly there will be a demand for environments that 'exist' even when not used, that have a history and even an ecology. Facilities for user authoring and ownership will be created. Additionally navigation will be tailored to a users task where this is appropriate.

There are also important social issues in the development of persistent virtual societies related to economic rules, behaviour and governance. Much of this revolves around issues of identity, which creates potentially complex scenarios.

These areas of DVE, and especially the use of avatars is a rich area of research challenges.

6.2 Telepresence – human interaction at a distance

Current systems deliver a 'through the window' experience with little sense of being within environments. The future will bring progress towards 'through the screen' telepresence, into the remote location. One approach is to use large screens with multiple projectors in simulated rooms which give an immersive effect.

Advances in processing power and display techniques giving improved real-time performance will add to the realism of these environments. Increasingly simulated real world's are being joined by 'mixed reality' systems and micro – or macro scopic realities. Personal headsets, as an alternative, are a credible commercial solution as they achieve improved display quality and become less cumbersome.

6.3 User Interfaces

Interfaces will evolve over the next 10 years away from the PC towards a state where information resources are distributed. Information devices will silently configure themselves and work out the capabilities of their environment. They will optimise access to networks and will operate anywhere by wireless or infra-red.

The richness and diversity of input and output devices will grow with mainly visual outputs through screens. Senses of sight, hearing and touch will be seamlessly integrated and used together to maximise bandwidth at the psychological interface. Natural language interaction, translation and interpretation of gestures will become a reality.

Systems will be able to detect the emotional state of the user and adapt. Body posture and eye movements will be tracked to assess levels of interest. Passwords will be replaced by biometric techniques. The interface with information systems will become a much more co-operative activity, with systems coaching users and suggesting ways of approaching problems.

These developments will need to be matched by a deeper understanding of the social and psychological issues surrounding the use of computers.

6.4 Electronic Commerce

The technical issues in implementing e-commerce are now largely solved although refinements can be expected. Security is often quoted as a barrier to e-commerce but in reality these can easily be resolved and the decisions which need to be made are political. The outstanding issues are political and regulatory and they are being addressed by various international bodies. Until progress is made on these issues, most significant ventures will operate in closed groups, along supply chains for instance.

Impacts of e-commerce are likely to vary significantly both geographically (culturally) and between sectors. However, there are major opportunities and the growth of e-commerce is likely to be spectacular.

6.5 Intelligent Information

Many businesses see that successful development will rely more on effective access to information both internally and externally. One way is to carry information with a product as it passes along a supply chain. A range of technologies achieve this for normal supply chains including electronic tags and smart materials.

However, the real revolution in this area is just beginning and there are major opportunities in inventory control, response times, countering crime and other areas.

6.6 Artificial Life (AL)

These technologies embrace ideas from many disciplines. The core algorithms from biology are starting to prove useful. Genetic algorithms (GA's) are used for parameter optimisation in high-dimensional problems. Real applications are piecemeal but they have promise.

GA's can be used in design of complex structures and materials. They can serve also as a model for autonomy and adaptive behaviour. They can be used for autonomous agents (robots) used in harsh environments or for assisting disabled people.

6.7 Agents of the Future

These software products are autonomous, controlling their own decision making and actions based on their perceptions of the environment in pursuit of a user's objective. They can act as personal assistants which learn about users to perform specified tasks. They can be information agents addressing the 'information overload' problem. They can be mobile, can work off-line or in real time. Their potential applications are immense and there is a widespread view that they will represent one of the major areas of development.

Most of the technology to support agents exists but in an immature form. Interoperability is a key issue. Agents do not share a common language and have great difficulty in communicating with each other. Applications are hindered by the problem of finding and extracting information from a network as chaotic and disorganised as the world wide web. This may be assisted by the adoption of content-description languages such as XML which may replace HTML as the common language of the internet.

Additionally more research is needed into human computer interaction if the constituency of users and the scope of uses is to be expanded. The desktop metaphor is now 20 years old and still too complex to be widely adopted by ordinary users who are comfortable with TV controls.

Another issue concerns management of networks themselves. Users are charged by time connected rather than bandwidth consumed. Yet most agents operate effectively by being permanently on-line. This would require a network capable of quickly routing and delivering data packets to say (in the UK) up to 50 million users simultaneously and charging for bandwidth.

6.8 Databases

Data storage and retrieval are based on structured databases (normally relational), search engines and hypermedia. These are old technologies and users are normally limited to in-built search mechanisms that accompanies the storage.

There is a need now for database systems which integrate stored data and search engines, which can cope with massive volumes of data and handle multimedia data as well as text. They need also to be able to handle problems of providing data to users in different environments and to handle synchronisation problems associated with linking to data in other locations, rather than replicating data.

There is no indication that simple evolution of current database strategies will achieve the change necessary. A fundamental and revolutionary approach is necessary and there is no indication of what that might be.

6.9 Information Management

This is at the softer end of level 3 technologies. The principal mechanisms of information management appear to be well established. However, it is taking many years for these mechanisms to progress from concepts to efficient implementation. Information management incorporates some of the technologies outlined above and a great variety of emerging systems and structures including:

- databases
- metadata techniques
- agent and agent management software
- intelligent information extraction services

Interestingly, there are areas where information management mechanisms are becoming redundant because of the ability of two or more users being empowered to work together and deal with issues in real time.

The real frontier in information management is therefore the development of metamodels which allow businesses to model their processes and tune the available technology to provide optimum access and use.

7. The Issues for Business

Technology will be a key and growing issue for all manner of enterprises.

Any enterprise that wishes to benefit from the new technologies will not only have to enable faster technical integration cycles but will need the right organisational structures and cultures to allow it to reorganise, understand and adopt advanced techniques rapidly.

Waiting to jump on the bandwagon till when it becomes a necessity leads to non-competitive business practices missed opportunities, low skill levels and anarchic architecture. On the other hand jumping on every new technology is what will sort out successful from unsuccessful enterprises.
Business analysts are concerned with what technological advances will trigger revolutionary leaps, how to identify them and the applications they will spawn and then how to create the most effective strategies for managing the ensuing changes to achieve business benefits. On the basis of current business thinking a number of more reliable assumptions can be adopted:

- speech recognition will become a standard part of computer environments
- allocation of 1T budgets to network (fixed and mobile) operations will escalate.

- generating competitive advantage will involve applications based on electronic marketing, delivery, support and market analysis
- successful business will be those which have early adoption of technologies that support key business initiatives
- any disillusionment about the Internet and network technologies will be centred around lack of applications rather than failure of the technology
- by 2006 successful business will have adopted high impact technologies

8. Emerging Technologies

Avoiding mistakes is helped by understanding the Hype Cycle whose phases are:

- Technology Trigger
- Peak of Inflated Expectations
- Trough of Disillusionment
- Slope of Enlightenment
- Plateau of Productivity

It is also helped by understanding that the cycle can be quick and there is a suggestion that for many technologies the phases are shortened as established technologies develop and mature.

Technologies, which require a research agenda, will be highest risk. This means that, amongst others, complex speech recognition, avitars and technologies requiring highly interoperable systems, remain uncertain. The question is can we identify the technologies that will generate maximum benefit? And in what time frames?

A number of areas have been identified by analysts as likely to be significant in IT developments through 2005. Significant for GIS educators and the GIS industry (and therefore for educators) are:

- mobile computing
- interactive media on the Internet
- consumer electronics
- knowledge retrieval

Mobile Computing

This area shows tremendous promise though to date it is much underused due to shortsighted planning poor training and poorly managed expectations.

Technology requirements and user requirements with mobile systems are different from static work in the work place or remote work. Mobile technologies will hit specific sectors first but will be slowed by Internet applications, security problems and partial quality coverage. In Europe and Japan, with good coverage, more rapid advances can be expected.

Interactive media and the Internet

There is inevitability about the use of interactive media and real time collaboration. These are proven technologies that promise real business benefits though their adoption is neither easy nor cheap.

Increases in bandwidth for LANS and WANS and the stability of IP4 will support developments but migration to IP6 will remain slow even with enhanced bandwidths. Adoption of streaming media and various other forms of real time collaboration will remain constrained by cultural factors.

Consumer Electronics

The highest quality of delivery will be from consumer technologies from set-top boxes to massive digital video discs. Prices will be driven down to the disposable entertainment range and these improvements for the consumer will create large discrepancies in expectations for other types of use. Watching the games markets provides a sort of benchmark for business and education sectors.

Knowledge Retrieval

Search technologies are moving towards the next generation. By 2002 information retrieval on the Internet will support decision making. Advanced semantic visualisation and collaboration tools will enable enterprises to achieve levels of knowledge management similar to those practices in science. The key question for business is whether or not it is possible to plan for these changes – and if yes then how.

8. Some Implications for GI Education and Training Provision

In much of the IT and education industries (sic) planning has not been the preferred response to likely change. In this situation it is IS departments which have controlled the enterprise responses to change in order to achieve business objectives. Only slowly will this responsibility shift back to business managers. There is a greater need to use strategic planning in these times of uncertainty. It will need to be continuous and situational and work with short time horizons into the foreseeable future.

Extrapolating these ideas to education we arrive at two sets of conclusions.

First, in relation to the market for GIS education in business:

- the need for education and training is highly dynamic. It changes in the same time frame as technology.
- education and training increasingly are an issue for senior managers both for themselves and as part of their business strategies.

- continuous and evolving education and training are critical to achieving business objectives
- planning for education and training within businesses will have shorter horizons.

Secondly, in relation to the business of GI education:

- GI education and training provision needs to respond very quickly to business needs, in the same time frames as technology change
- education and training provision should be aimed at all levels
- education and training should be aimed at business objectives and at critical areas for achieving business objectives
- education and training provision needs to be planned for continuous development and to be tightly linked to business needs

To these another conclusion can be added:

- GI education has to be tightly linked to mainstream IS/IT education

9. Trends, Challenges and Risks for GI Education Provision

9.1 Trends in Technology

The context for education is 'technology change' not only in the field of study but in education and training products.

Within two years we could have:

- cheap high bandwidth mobile computing
- cheap ultra high quality displays
- virtually limitless cheap memory
- wearable computers
- universal capacity for some speech recognition
- intelligent information gathering and management
- an accelerating rate of change in many of these technologies

9.2 Challenge from Technology

There are clear challenges for education provision using these technologies. These challenges will be driven by user expectations, business need and competition between educators.

The key challenge is

- rapid development of education materials and delivery

But around this are a number of equally demanding challenges

- design of education materials with different levels of granularity
- design incorporating good pedagogic practice
- the creation of new educational scenarios. To the "just for you" and "just in time" catch phrases can be added "just enough" and "just here and now"
- the challenge of the power shift in Quality Assurance from the provider to the market

9.3 Trends in Operations

Looked at from a business perspective the entire education sector world-wide must appear a complete anachronism. It has appalling business processes, poor marketing, poor pricing, is technically backward and is over burdened by bureaucracy. There are far too many operations surviving on customer loyalty and on a poorly informed market. It supports far too great a diversity of products, many of which are drains on resources. It operates on questionable business principles (myths) of quality, reputation, status and non-tangible value of its products. In short it is a mess and this is increasingly recognised both by a small number of senior managers in education and by the commercial sector who see the potential for an education market.

The last few months have seen shifts in the business structures in education, which reflect these concerns. There is an increasing number of on-line universities, the emergence of "universities" from the business sector and the establishment of business alliances between traditional universities. And behind these alliances are signs of major shifts in the internal structure, operations and product lines of these traditional institutions.

Another established and accelerating process of change is the provision of Internet based learning portals or gateways with their increasingly powerful search and information management tools. The horizon of educators and students has expanded enormously. Additionally there are now emerging the tools for managing learning and learning provision based on these new technologies. There are two main areas. The level 2 technologies, for provision such as the Institutional Management Systems (IMS) initiative. The level 3 technologies which have a long ancestry (in network computing terms) but so far little penetration of the mass market for education. These can be put under the umbrella of Managed Learning Environments (MLEs). What is important here is the convergence of processes of change in the education business with process of change in education provision and management which are enabled by technology. That convergence has not yet happened but in an increasingly competitive world of education provision it is inevitable.

9.4 Challenges for Education Provision

The challenges for education provision are complex and perhaps more severe than from technology alone since they relate to the educational organisational culture, personnel and management capabilities.

It is possible to identify what some of the challenges are (not "will be" since it is clear from the rest of this paper that radical change is upon us).

The key challenges are:

- specification and partitioning of markets
- formation of strategic and operational alliances of all sorts
- the creation of non-standard qualifications to meet market needs
- business processes re-engineering in education
- merging of traditional education and commercial education systems

9.5 Risks

There are many risks to the continuing successful adaption of GI education to its changing operating environments. Only a few, regarded as key issues, are mentioned here.

- A focus on the "hot margin" of technology with consequent neglect of business needs and market opportunities.
- Neglect of legacy materials, legacy delivery and the mix of new and legacy technologies.
- Poor management, lack of vision, poor leadership, aversion to taking risks.
- Organisational cultures resistant to change, 'non-learning' cultures.

A pervasive and overarching risk is the unawareness and lack of development of appropriate pedagogic models for design, delivery and support of education and training.

Technology is forcing the move to provision 'just for you' and 'just in time'. This requires flexible on-line learning environments. But achieving this requires a student culture for learning from CAL. New sets of relations between students and educators have to be established and better design frameworks for student-tutor interaction have to be adopted (Laurillard, 1993, see also http://www2.open.ac.uk/ltto/diana.html). Learning community and support have to be key words in educational strategies.

Higher education in the UK (and elsewhere) is notoriously slow in changing its structures, practices and attitudes and this whole area of pedagogic development is therefore the most likely to be the most critical risk for most providers.

10. Vision of the Future

Bob had just been given responsibility by the Director of the building firm for assessing the environmental impact of new building developments. His computer assistant has immediately notified him of a development for which the deadline for his report is only three days away. He logs onto the data sites for the site and sees the local planning authority, the water authority, an environmental group and a local residents group have expressions of interest and already have been working with the data proof.

Bob, a building engineer hasn't much experience of working with GIS data, so he tells his computer to call 'Echo' the intelligent tutor. Echo takes him through the analysis stages of the other groups stopping only when Bob asks a question. As a beginner he enables the intelligent cartographic facility so at least his mapping will look professional. When Bob asks why the water company has asked to look at road traffic data Echo says he should refer to their modelling monitor but, reading his professional development file, suggests he first does some homework on runoff chemistry. It recommends a tutor and provides him with a call up button on his monitor and on his mobile. Bob decides to call it a day, says 'bye' and heads off to catch the train home.

Only a 30 minutes trip he thinks but I can catch up on runoff chemistry before I set home. He takes his phone out, presses the tutor button and spends the next 15 minutes viewing a short presentation from Prof. Kandeski of Moscow State University. His personal development counter registers another unit and MSU registers another dollar (US). Not bad at that price he thinks, and I've got another couple of questions for the pub quiz tonight.

11. References

ITEC (1999) ITEC Technology Forward Look Paper, An Analysis of Information Technology Trends and Futures, http://www.foresight.gov.uk/frame_publications.htm.

Laurillard, D. (1993) Rethinking University Teaching, Routledge, London.

12. Glossary

Active X	Microsoft technology for facilitating information sharing amongst applications search http://www.microsoft.com/
ADSL	Asymmetrical Digital Subscriber Loop http://www.adsl.com/adsl_forum.html
AL	Artificial Life http:/alife.santafe.edu/index.html
CCD	Changed Coupled Device
CORBA	Common Object Request Brother
CRT	Cathode Ray Tube
DCOM	Digital Compression http://ww2.divi.com/co_info/tombook/book.html
DCOM	Distributed Component Object Model to support objects distributed across a network search http://www.microsoft.com
DLP	Digital Light Processing
DNS	Domain Name Server

DVE	Design Virtual Environment
GA	Generic Algorithms http://gal4.ge.uiuc.edu/links.html
IP4	Internet Protocol v.4 http://www.whatis.com/p.htm
JAVA	Platform Independent Language from SUN http://java.sun.com/ http://metlab.unc.edu/pub/sun-info/standards/xml/why/xmlapps.html
LAN	Local Area Network
LCD	Liquid Crystal Display
PKI	Public Key Infrastructure http://www.pca.dfn.de/eng/team/ske/pem-dok.html
SLM	Spatial Light Modulator
SMIL	Synchronised Multimedia Integration Language
SSL	Secure Socket Layer
STEP	Standard for Exchange of Product Model Data http://www.steptools.com/library/standard/ http://www.steptools.com/office/other_sites.html
TCP	Transmission Control Protocol used in TCP/IP networks
URL	Universal Resource Centre
USDL	Very high rate digital subscriber line http://www.analog.com/publications/magazines/comm/vol2_no2/splighton2_2.html
VRML	Virtual Reality Mark Up Language
WAN	Wide Area Network
x500 Certificates	Network Protocol for Authentification and Security