

3 The Continuing Evolution of ICT Capacity: The Implications for Education

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Introduction: General Trends in ICT Capacity

The capacity for information and communications technology (ICT) has been growing exponentially over the last 10 to 15 years. Computers have become more powerful; satellite, fibre optic and wireless technology has increased transmission capacity; and software developments such as multimedia authoring systems have made it easier to create digital materials such as electronic games, computer simulations and educational materials.

The increased capacity and supply has resulted in plunging prices for computer functionality, telephone services and software. Nowhere has the impact been greater than on the telephone industry. Long distance charges in North America and between major developed countries have dropped by 90% in the last 15 years. Some analysts believe that the Internet will transform the pricing structure for telecommunications from charges by distance and time to a flat charge by capacity. Thus a client will pay according to the size of the "pipe," not by the distance or length of time for which it is used. It should be noted that while the growth of the Internet is one of the major drivers for change, it is only one of several different but converging technologies that are resulting in widespread capacity growth.

The rapid growth in satellite and wireless technology, and in particular the growth in mobile phone technology, is resulting in some countries attempting to leap beyond previous or intermediate technologies. For instance, telephone capacity in China had been limited by lack of hard-wired networks. Mobile phone technology is allowing for a rapid expansion of telephone access in China. It is the last link to the end-user that has previously made hard-wired networks expensive to install on a widespread basis. Wireless technology avoids the need for hard-wired circuits into homes and offices.

However, there are several conditions surrounding this rapid growth in ICT, which can be summarised as follows:

- Despite the recent adjustments to world stock markets, capacity in ICT is forecast to continue to grow rapidly. For instance, while both Cisco and Nortel, the main providers of network hardware for the Internet, have revised downwards their growth forecasts this year (2001), both anticipate continued growth of 15% or more annually for the next five years. This suggests that access, bandwidth and applications will all continue to increase into the foreseeable future.
- The technical capacity has far exceeded the capacity of governments, commercial

organisations and educational communities to respond fully to the opportunities and challenges this rapid change has brought.

- ICT growth is not equal between different countries, between different socio-economic groups within countries or within different economic and social sectors of society. This inequality is often referred to as the digital divide: the gap between those with access and with the skills to use ICT appropriately, and those who do not have this capacity.
- Free trade and lower labour costs in developing countries in manufacturing and in resource-based industries such as agriculture and forestry have forced many former industrial nations, as well as some newly emerging “economic tigers” such as Malaysia and India, to move more aggressively into knowledge-based businesses heavily dependent on ICT technologies. Thus there has been a rapid growth in e-commerce, software development, hi-tech design (such as micro-processors, digital routers, computers and digital telephone switches), entertainment (video and computer games, film and television) and financial industries in developed countries. Such knowledge-based businesses both exploit the advantage of a highly educated workforce and, at the same time, drive the demand for an even *more* highly educated workforce. Much of this growth has occurred in smaller, more dynamic companies that avoid hierarchical management structures. The development of alternative organisational and management structures for the new knowledge-based industries is also relevant to virtual education, which is not only dependent on an extensive and reliable ICT infrastructure, but also requires a post-industrial approach to organisation and management.
- Technologies such as wireless and the Internet are disruptive in the sense that they bring about

radical change to previously stable sectors. Companies such as Apple, Netscape, and amazon.com have helped revolutionise certain industry sectors, forcing previously dominant corporations either to radically change their operations or to close down. These same forces have the potential to bring about similar changes in the education sector.

Given the impact of ICT on many businesses and industries, it is not surprising that many commentators have seen education as being potentially revolutionised by it. Hence, there is great interest in virtual education, which is based on the idea of a widespread and significant application of ICT to the core activities of education.

However, despite a great deal of hyperbole about the potential of ICT for education, real growth and change has been slow and marginal. This is due not only to lack of vision or commitment by educators and policy-makers; there are significant structural and cultural barriers or restrictions that have slowed the potential for change in education compared with other sectors.

These issues are discussed below, first looking at some case studies, then examining what kinds of technology are being used and why. Following that is a brief examination of some key emerging technologies and how they may have an impact on the education sector.

Brief Case Studies of Major ICT Applications in Education and Training

As there is a very wide range of different applications of ICT in education, any choice of case studies is somewhat arbitrary. For example, the Open University in the U.K. (UKOU) has been using communications technologies such as broadcast television and radio for educational delivery since the early 1970s, and in recent years it has also moved into online programming.

However, print still remains the core delivery medium for the UKOU, even though it has expanded its programming into Europe and other areas of the world.

Similar “dedicated” national open universities, such as Indira Gandhi National Open University in India, the Chinese Central and State Radio and Television Universities, and the Korean National Open University, have operated for many years, primarily on a mix of broadcasting and printed materials. Other dedicated open universities, such as Athabasca University in Canada, have moved more aggressively into Web-based delivery.

At the same time, many institutions that offer both campus-based and distance programmes, such as the University of British Columbia (UBC) in Canada, Charles Sturt University in Australia, and Penn State University in the U.S.A., have begun to move their former print-based distance education courses online. For instance, UBC has over half of its 110 distance courses now online. In Korea and several other countries, campus-based universities are forming consortia for the delivery of online distance learning programmes.

However, the most dramatic change in the use of ICT has not been in the traditional distance education market. The biggest impact has been on campus-based teaching and in the private sector training market. John Chambers, the CEO of Cisco, one of the world’s largest ICT companies, has stated that “the next big killer application for the Internet is going to be education” (Moe and Blodget, 2000). Merrill Lynch has described e-learning (the combination of the corporate learning and higher education markets) as a U.S.\$18 billion market by 2003, compared with \$2.3 billion market in 2000 (Moe and Blodget, 2000). Here are just a few examples:

- WebCT, a course authoring software platform, has over three million student licences in over 1500 institutions, and it is growing at a rate faster than 500,000 new student licences a year. However, WebCT estimates that over

80% of the use of its software is to support classroom teaching rather than “pure” distance education. Thus we are seeing the emergence of “mixed mode” teaching, combining face-to-face instruction with online learning. One of the best examples of this is the University of Central Florida, which has an extensive programme of Web-based courses available both to on-campus and off-campus students (see www.distrib.ucf.edu/present/FETCpresentation030100/index.htm for details of its online course strategy).

- A number of universities have formed consortia and partnerships with the private sector to commercially exploit their e-learning initiatives. Universitas 21 is a network of 17 universities in mainly Commonwealth countries, including Nottingham University, University of Edinburgh, University of Melbourne, Hong Kong University, National University of Singapore and the University of British Columbia. Thomson Publishing and Universitas 21 have announced a partnership to found an “e-university.” In 1990 there were 48 million people in higher education (Moe and Blodget, 2000); by 2025, Thomson Publishing estimates that there will be 160 million.
- UNext, a U.S. company, has established an e-university called Cardean (www.cardean.com/cgi-bin/cardean1/view/public_home.jsp) that adapts its teaching material from that of the universities of Columbia, Stanford, Chicago, Carnegie Mellon and the London School of Economics. Degrees are awarded under the Cardean name, endorsed by the state of Illinois.
- The London School of Economics (LSE) is also more deeply involved in an e-learning venture called Fathom (www.fathom.com), launched last year as a global online library linking institutions such as the New York Public

- Library, the British Library, the Smithsonian, the Cambridge University Press and the LSE. Fathom's partners participate in the running of the service, and all must approve materials before they are published on the site.
- The U.K. government has established one of the most ambitious joint e-university projects. It has put the Higher Education Funding Council for England (HEFCE) in charge of attempts to create an e-university with a budget of £400 million, half of which will be public sector money. At first this was intended to be an exclusive arrangement, with universities bidding to become members. But now all U.K. universities are allowed to hold shares. The only human contact in the core programme will be with “navigators” — advisers who will help new students to select courses. Only those students who attend summer schools or pay for additional tutorial support will receive face-to-face tuition.
 - Oxford University is linking with Stanford, Yale and Princeton to create an online college for alumni. The idea is to provide life-long learning and support to some of the world's policy-makers and business leaders. Cambridge is exploring virtual learning in its £83 million government-backed link-up with the Massachusetts Institute of Technology (MIT). The project is known as the “bridge of minds” and is principally intended to foster commercial spin-offs from university research. It also has potential to become an e-university.
 - A U.S. company, Hungry Minds (www.hungrymindsuniversity.com), has contracted with Michigan State University, New York University, Penn State University, Rochester Institute of Technology, University of California Berkeley Extension and University of California at Los Angeles Extension to provide a range of e-learning services. These vary from providing a common Web portal for their courses, to supporting the development of online certificates by these institutions.
 - Since 1996, the University of British Columbia (UBC) has been offering a fully online graduate level programme on technology-based distributed learning in partnership with the Monterrey Institute of Technology in Mexico (<http://itesm.cstudies.ubc.ca>). The core of the programme is on the Web, but UBC also participates by video-conference link from Vancouver to Monterrey in satellite television broadcasts to Monterrey Tech's 29 campuses across Latin America. Monterrey incorporates the five courses in its own master's degree in Educational Technology and has the rights to offer the five courses throughout Latin America. UBC has made the five courses available to both its own mainly campus-based master's students as well as to the rest of the world as a post-graduate certificate programme. To date, it has recruited students from more than 30 different countries. This programme runs on a self-financing basis entirely from student fees. As a result of this experiment, UBC and Monterrey plan to offer a joint master's degree in educational technology in both Spanish and English on a global basis from January 2002.
- In the private sector training area, there has been a rapid expansion of “corporate universities,” primarily in-house training organisations in the larger multinational companies making use of video-conferencing and the Internet. In parallel, there has been the development of a whole new industry of online training contractors who provide online training services to medium- and smaller-sized companies. Almost two-thirds of Merrill Lynch's estimated \$18 billion market is in this private sector training area.
- A number of private, for-profit organisations are trying to bridge the gap between centralised

distribution (such as foreign Web courses or satellite TV) and local support. For instance, TeltecGlobal (www.teltecglob.com) is a “business services aggregator” offering corporations and governments “a one-stop, turn-key solution for access to 21st century technology, services and education.” The TeltecGlobal Center of Influence is a “last mile” strategy that provides customers with products and Web-enabled services available through membership in their Community and Business Centers located in developing countries. TeltecGlobal Community Centers work in conjunction with multinational corporate sponsors, designing an offering of products and services “to meet both community needs and corporate objectives.” Business Centers license operations to local entrepreneurs and “global government-backed entities” in emerging markets. As with the Community Centers, TeltecGlobal works with the licensees to tailor the products and services to market needs and licensees’ goals. TeltecGlobal is a good example of the increasing synergy between technology, education and business.

These developments are not so different from the chaotic, diverse and excessively optimistic developments in the dot.com business sector. Indeed, especially in the U.S.A., e-learning is seen as just another branch of e-business. However, a more careful analysis of these developments will indicate that there are many barriers and challenges that need to be overcome before such initiatives can operate on a sustainable basis.

What Kinds of Technology Are Being Used?

WORLD WIDE WEB

The predominant technology being used for e-learning in the developed world is the World Wide Web, which in turn relies on the Internet. At the end of 1999, more than 196 million people globally were using the Internet; by the end of 2004,

the number is expected to rise to 638 million (Moe and Blodget, 2000).

There are many reasons for the rapid application of the Web in education:

- Through the use of browsers and a relatively simple programming language (HTML), the Web provides universal standards and interoperability between different machines and operating systems, which allows for global reach and access.
- The Web can be transmitted both through already-existing infrastructure, such as analogue telecommunications networks, as well as through high-speed digital networks, giving it a wide range of technical flexibility.
- The Web is a low-cost technology for education for several reasons:
 - There is a relatively low cost of entry for educational suppliers. The cost of the technology needed for online courses (such as a server and course authoring software) is marginal compared with already-existing infrastructure costs for business and administrative purposes (computers, communications network, etc.).
 - Development of materials is relatively low cost because of a simple computing language (HTML) for creating materials and the development of intermediary course authoring software (such as WebCT and Blackboard) that enables Web sites to be easily constructed.
 - Through its use of the Internet, there is no direct charge for independent packets of information (as is the case with voice telephone calls); pricing is by volume (the size of the pipe into the institution), not by time or distance. Since most current applications use narrow bandwidths, the transmission costs per course for the supplier are virtually zero.

- The Web's ability to combine text, graphics and a limited amount of multimedia gives it a wide range of applications in education.
- The Web enables free and global access to a very wide range of high quality (as well as low quality) learning resources located on Web sites.
- The Web offers opportunities for international, cross-cultural and collaborative learning.
- The Web enables learners to study at any time and, increasingly, from any place.
- The Web allows asynchronous (time-delayed) interpersonal communication, not just between instructor and student, but more importantly, between learners and other learners, through e-mail, bulletin boards and online discussion forums.
- Most applications of the Web still have to fit into narrow bandwidths, limiting educational materials to text and static graphics.
- To fully exploit the educational advantages of the Web, teachers need to adapt and change their teaching methods. Without adequate support and instruction, teachers will merely add cost to the current system by bolting on the technology to traditional classroom methods.
- Teachers also need technical support, both in terms of ensuring the networks, software and equipment work properly and are adequately maintained, but also in the design and development of Web sites. This requirement adds substantially to costs.

This last point cannot be stressed too strongly. The ability to enable students to communicate with each other independent of time and distance moves distance education away from a transmissive, teacher-dominated model of education to a more interactive form of learning where students can adapt and apply learning to their own needs. In a knowledge-based society where information and knowledge are rapidly increasing, it is essential for students to be able to question, discuss and analyse their learning in a social context.

However, there are several constraints that limit even greater expansion of the Web as a learning technology, particularly in developing countries:

- In many developing countries, and in a small but significant number of communities and homes in developed countries, the necessary minimal technology infrastructure needed to support the Web — a computer and a telephone — simply do not exist.
- Even where the minimal infrastructure is in place, many people do not have the necessary computer, keyboarding and literacy skills to make effective use of the Web.

- The interactive, participatory form of learning that has developed around the use of the Web is culturally unsuited to the predominant mode of teaching and learning in traditional societies, which give great respect to the teacher, and where students are not expected to question the wisdom of elders.
- To justify the expense and stress of major changes in work methods, Web-based learning needs to be used strategically and be adequately resourced. However, many administrations lack both the vision to use it for strategic change and the willingness to reallocate sufficient resources to ensure success.

SATELLITE BROADCASTING

Another technology that is being used extensively in education is satellite broadcasting. Satellite television for educational purposes has a long history dating back to the early 1980s. India was one of the first countries to use satellite television through the INSAT project, and today Indira Gandhi National Open University is still a major satellite user. The Chinese Central Radio and Television University is another major user, with over

800,000 students. Monterrey Tech in Mexico (www.itesm.mx) has four satellite TV channels operating 24 hours a day, seven days a week, covering large parts of Latin America. It is used primarily to deliver lectures from its headquarters in Monterrey, and it provides two-way communication through e-mail questions from students to the studio host in Monterrey.

In North America, satellite transmission has become more and more integrated into a broader range of communications technologies, combining television, telephony and data transmission. There, satellite TV is now mainly used for educational purposes to cover relatively sparsely populated areas (e.g., The Knowledge Network in British Columbia), or for special educational events, such as forums on topics of interest with highly respected speakers. It is rarely used as the main technology for formal education courses, although the National Technological University (www.ntu.edu) in the U.S.A. uses satellite TV to provide graduate engineering and business courses to corporations.

One satellite application of particular relevance to poor developing countries is WorldSpace (www.worldspace.com). Headquartered in Washington, D.C., the WorldSpace business was founded in 1990 to provide direct satellite delivery of digital audio communications to the three-quarters of the world population that lacks radio reception and programme choice. New digital technology combines low-cost radios with direct satellite reception using small, portable satellite receivers developed specially for the project by some of the world's leading electronic companies (e.g., Hitachi, JVC, Panasonic and Sanyo). WorldSpace obtains programmes from regular broadcasters such as the BBC. It started operations in Africa but has recently extended its services to Asia. Its potential audience is now approximately three billion.

The African Virtual University (AVU), initially developed by the World Bank, is another

initiative using satellite television broadcasting (www.worldbank.org/knowledgebank/facts/avu.html). AVU uses ICT to give the countries of sub-Saharan Africa direct access to high-quality academic faculty and learning resources in Africa and throughout the world. Professors from universities around the globe deliver classes in a studio classroom. The course is then beamed by satellite to AVU's learning centres all across Africa, each of which is equipped with an inexpensive satellite dish to receive the signal. During the class, students have an opportunity for real-time interaction with the instructor using phone lines or e-mail. At each participating AVU learning centre, on-site moderators guide the students through the materials and act as liaison with course instructors. All learning centres are equipped with Internet access and at least 50 computers.

Since the launch of its pilot phase in 1997, AVU has provided students and professionals in 15 African countries with more than 2500 hours of interactive instruction in English and French. More than 12,000 students have completed semester-long courses in engineering and the sciences, and more than 2500 professionals have attended executive and professional management seminars on topics such as Y2K, e-commerce, entrepreneurship, and strategy and innovation. AVU also provides students access to an online digital library with more than 1000 full-text journals. More than 10,000 students and faculty have opened free e-mail accounts on the AVU Web site. It has established itself as an independent, non-profit organisation headquartered in Nairobi, Kenya. During the next three years, AVU will expand to more countries in Africa and reach undergraduate students, faculty and professionals through three main avenues: learning centres in universities, private franchises and professional learning centres housed in corporations and non-governmental organisations.

Satellite broadcasting has the following features relevant to education:

- Because of the relatively high infrastructure costs (studios, satellite transmission and receive sites), it has high fixed costs but very low variable costs; this makes it most effective when many students (usually numbered in thousands) can receive a single programme.
- It provides a common standard of lecture or teaching to all students, wherever they may be located.
- It fits a transmissive model of education, where students are expected to remember and understand what is being taught.

Satellite broadcasting suffers however from the following constraints:

- It requires very high start-up costs and a high level of technical expertise to launch and maintain.
- Despite the use of alternative technologies for two-way communications such as telephone and e-mail and the use of local teacher-supported discussion groups, it is difficult to make satellite broadcasting very interactive for learners.
- Learners with Internet access have less flexibility in terms of time and place of study from satellite broadcasting than from studying through the Web, being tied either to the time of the broadcast or to a fixed location if they do not have personal access to satellite reception equipment.
- The need to provide convenient, secure and accessible local reception sites can add substantially to the cost, especially for satellite TV.
- Satellite TV lacks the educational flexibility and the future potential for improvement that can be found in the Web.
- Governments appear to be less willing to regulate and fund educational satellite TV

initiatives, partly because of the high cost, and partly because of a move to more deregulated communications policies. In such a context educational users are usually unable or unwilling to pay full commercial rates for satellite transmission costs.

In short, satellite broadcasting has advantages for transmission of information to large numbers of students at relatively low cost per student. However, satellite broadcasting needs strong local support on the ground, through local centres or alternative two-way communication channels such as telephone or the Internet. These ground costs and the constraints on learning considerably reduce the economic and educational benefits of satellite broadcasting. Furthermore, well-designed printed texts can be more educationally cost-effective than real-time or even recorded satellite lectures.

VIDEO-CONFERENCING

Video-conferencing is also widely used for educational purposes, particularly in the U.S.A. and Australia, to link multi-campus colleges and universities, and for corporate training in companies with multiple sites. Video-conferencing makes use of fibre-optic cable or copper-based telephone networks and computerised compression technology to “squeeze” the high bandwidth requirements of full motion analogue television into a narrower bandwidth.

Video-conferencing is used in education for the following reasons:

- It saves instructor and student travel time between dispersed campuses, making possible the availability of some classes in sites away from the main campus.
- Teachers do not have to make significant adaptations to their normal method of classroom teaching (although special efforts need to be made to ensure students at the remote site participate in discussions and class activities).

- For corporate training the cost savings can be substantial, mainly due to savings on travel and accommodation.

There are, however, significant constraints that have prevented a wider use of video-conferencing in education:

- There are substantial installation costs, not so much for the video-conferencing equipment, but for modifications to classrooms to ensure adequate lighting and, in particular, good-quality sound. Transmission costs, especially with heavy use, can also be substantial.
- Students still have to be at a set place at a set time.
- While video-conferencing allows for more active participation by remote students than satellite TV, the larger the class the more difficult it is for all students to participate.
- The limited visual cues from the remote site and the often poor sound quality makes it a stressful environment for both students and teachers.

Video-conferencing can also be transmitted through the Internet, but currently bandwidth severely restricts Web-based applications. It is now possible to have real-time audiovisual communication between two desktop sites using relatively low-cost digital cameras and software (approximately U.S.\$100 per workstation). Picture quality is poor though, and there are still major bandwidth limitations preventing multiple site video-conferencing over the Internet. Thus there have been few or no Internet applications of video-conferencing to date for regular course delivery.

In short, the technical constraints of video-conferencing limit its potential for use on a wide scale, but it can be useful as an additional resource for virtual education when used in support of the Web. It can be particularly useful for language teaching and for areas where technical or interpersonal processes need to be observed. Eventually,

though, video-conferencing is likely to migrate to the Web when bandwidth increases.

COMPACT DISK TECHNOLOGY

Lastly, compact disk technology, in the form of CD-ROMs or digital video disk (DVD), is being used in a number of interesting ways in virtual education. These disks tend to be used for applications requiring large quantities of data in real time, such as multimedia applications. The disks can run on the student's local computer in conjunction with the Web; the codes on the disk are accessed from a Web site, which can then call up images from the disk. Students can then seamlessly move between Web site and disk, thus overcoming many of the bandwidth constraints of the Web.

The increased capacity of CD-ROMs and particularly DVDs facilitates a wide range of educational applications:

- Large stores (databases) of slides, photographs or computer-generated images, each one digitally coded and catalogued, can result in the same CD-ROM being used in a variety of different courses.
- Video clips or learning objects often require too much time for downloading over the Internet. Compression techniques now allow for high-quality video digital reproduction on CD-ROMs or the even greater capacity DVDs.
- Simulations enable students to enter data and see the consequences.
- A virtual lab can simulate many of the experiments and practices demonstrated in labs without the time required to set up experiments and equipment and with no worry about lack of convenient space.
- Expert systems, somewhat like games, can help students make decisions and see the consequences. The outcomes are governed by rules and procedures based on expert

knowledge. Expert systems are valuable in facilitating decision-making in complex contexts. One example is QUEST (www.sdri.ubc.ca/GBFP/index.html), which allows students to project a desired future for the Georgia Basin region of British Columbia, then examine the consequences of decisions taken now to move towards the desired future. William Massey of Stanford University has also developed an expert system that enables the learner to play the role of a university president (www.virtual-u.org). Web-based expert systems allow several players to interact not just with a central computer, but also with each other.

The main constraints of disk technology are as follows:

- The cost of development is very high (although duplication and delivery is now very cheap; it costs UBC's distance education department about U.S.\$3 to duplicate and deliver a CD-ROM to a student). This means that compact disks need to replace otherwise very costly activities (such as flight training) or be used on a large scale.
- Teams of highly skilled media producers and developers, as well as subject experts, are needed.
- Learners need a relatively high standard computer and disk player because of the memory and processing requirements.
- There can exist a lack of imagination and vision in thinking of how the technology can be used for teaching purposes.
- There is concern that this a temporary technology that will be replaced when wide-band access is available over the Web.

CDs and DVDs are high-end educational applications of technology. While they indicate some of the possible future developments on a more universal scale over the Internet, good-quality

disk-based educational applications are very expensive to develop and require high skill levels. However, as more and more high-quality materials become available on disks, there will be opportunities for course developers to incorporate off-the-shelf disks into their own local programmes.

SUMMARY

In summary, the Web is becoming a dominant technology where people have access to it. Because of its capacity to reach thousands of learners with a service of a defined standard, satellite broadcasting still plays a valuable role in many developing countries where a large number of learners do not have access to the Internet. Videoconferencing, on the other hand, has limited uses, is dependent on very low telecommunications costs and lacks the flexibility and potential of the Web. Computer disk technology continues to evolve and opens up a wide range of powerful educational applications. Development costs, however, are high, and hence limit its use to specific high-cost areas of education or training, or to commercial development for mass marketing.

Key Emerging Technologies

Because of the rapid rate of technological change, it is important to look not just at what is existing now, but what is also likely to happen over the next five years. A number of related and interlinked technologies that could have major implications for teaching and learning are now clearly emerging.

INTERNET AND THE WEB

The Internet and hence the Web will continue to develop. Access will widen as governments put in place national strategies such as linking all schools, providing community access and investing in infrastructure. As well, competition in a

deregulated market will also widen access. Telephone companies, satellite operators, cable TV operators, and equipment companies such as Cisco and Nortel will all compete and market aggressively to provide the basic Internet infrastructure in North America.

A recent consumer technology study by PricewaterhouseCoopers indicates that Canadians have the highest home use of the Internet in the world, with 48% having home access in 2000 (see Table 2.1).

Table 2.1

Internet use at home
(by percent of population)

Country	2000	1999
Canada	48%	43%
United States	44%	43%
Europe	26%	17%

PRICEWATERHOUSECOOPERS, 2000 IN EADIE (2000).

It is important to note the trends in Internet use as well as the static data. If the diffusion of computer use follows that of other domestic consumer technology trends, at least two-thirds of Canadians will be using the Internet from home within five years. Nevertheless, research shows that the use of computer-based technology increases with education level, and the bias for home Internet use tends to be towards high and upper-middle income families. Thus there will always probably be a small percentage of low-income or other disadvantaged individuals who will not have home access.

While the majority of Canadians are still accessing the Internet via telephone, broadband use (cable, ISDN, DSL) is rapidly increasing (see Table 2.2). Recent industry projections from cable and telephone companies are that more than half of all Canadians using the Internet will have broadband

access by the end of 2002. While Canada may currently have the highest Internet penetration, the same trends for greater access and increased bandwidth will continue in most countries.

Table 2.2

Main method of Internet access from home in Canada (by percent of users)

Method	2000*	1999
Phone line	58%	66%
Broadband (cable or ISDN)	29%	n/a
Other	3%	n/a

* The totals do not add up to 100% in the study.

PRICEWATERHOUSECOOPERS, 2000 IN EADIE (2000)

The move to broadband applications and the need to develop sustainable business models for e-commerce could also have an impact on the current pricing structure of the Internet. Its current flat rate pricing by volume may give way to pay-per-service use, especially once it becomes technically feasible to deliver on-demand television and movie programming over the Internet (see Platt, 2001, for a more detailed discussion of this issue). This may make the Internet less appealing to potential learners, although it may make it more appealing to service providers.

The rapid development of Internet services and reach in North America is also fueled by the relatively low cost of the services to the home and work place. This pricing, in turn, is driven by strong competition within the communications industry. Deregulation of telecommunications underlies this strong competition. Some countries may have strong national and social reasons for maintaining a single national telecommunications carrier or a closely regulated telecommunications system, but the cost of Internet services will be much higher in those cases and, hence, the use of the Internet much lower.

Such rapid spread of the technology and the increased bandwidth will have major implications for educational use. The issue then for most countries is not the direction of change, but the speed of that change. The Internet is not going away; its use is going to increase in all countries. But how fast that increase occurs will be determined primarily by economic development capacity (the ability to invest and pay for services) and by the technical ability within a country to develop and maintain the necessary Internet infrastructure. However, some countries will try to manage the market and control access to the Internet, through political means, which could slow down its development regardless of economic development and technical ability.

WIRELESS TECHNOLOGY

A second area of major technological development over the next five years is going to be wireless technology. This technology is already manifested in mobile telephony and will increase to hand-held devices such as Palm computers and laptop computers. For instance, on arrival at the Monterrey Tech campus, students can obtain a small chip to put in their laptops to enable wireless Internet access anywhere within their campus environment. The technology is cheap and will become cheaper. This means that learners will have great mobility and be able to access learning while travelling (on buses or planes, for example) or in a café without having to be hardwired.

LOCAL POWER GENERATION

Local power generation is another development that will overcome some of the infrastructure difficulties in providing a reliable Internet service. The Internet depends on a reliable and stable supply of electricity. The development of low-cost local power generation technology reduces the need for huge central investment in national power grids to reach all parts of a country. Small local power plants are springing up to offer neighbourhood

users cheap electricity, thanks to not having to pay for distribution over a wasteful national grid. An added advantage of so-called “micropower” is that it will be much friendlier to the environment as well, when it is based on fuel cells that convert hydrogen direct to electricity without combustion (see *Economist*, Feb. 2001 and Mar. 2001 for a more detailed discussion of this issue).

SPEECH RECOGNITION SOFTWARE

Another area, and perhaps the most significant of all for computer use, is going to be speech recognition and voice and text translation (*Economist*, 2000). Speech recognition software from companies such as Lucent, Nuance and Speechworks can now understand a wide range of accents and diction without having to be trained to a specific voice. Computer languages such as VoiceXML now make it possible to write voice services in the same way that HTML makes it possible to write Web pages. With VoiceXML, the human voice becomes a substitute for a computer mouse and the spoken command for a click. The graphical user interface consisting of a keyboard and mouse is likely to disappear as a result. Full communication with a computer in the same way as with human beings may never become a possibility, but after many years of false starts and false hopes, speech recognition technology has now reached a stage where it has become reliable, cheap and useful.

The importance of this development is that it will change the nature of interaction with computers. Word commands will make it easier to operate a computer, particularly for people with relatively low literacy skills. This, in turn, will have major implications for the design of learning materials.

MACHINE TRANSLATION

Lastly, developments in machine translation will have significant implications for the use of the Internet. According to Global Reach

(www.gltreach.com), English is currently the predominant language of the Internet, with 48% of all Internet users being English-speaking. However, the predominant Internet languages are expected to change dramatically over the next five years. The numbers of Chinese-speaking users, which now account for just 7% of all Internet users, is expected to surpass the number of English-speaking users within five years.

It will become increasingly important for educational programmes to be available in a wide variety of languages if they are to be offered not just on a global basis, but also within multicultural communities. One way to do this is through joint course development between bilingual teams. This is the strategy of the UBC/Monterrey Tech partnership. The courses will not be translated, but will be designed in both English and Spanish, covering similar ground and as far as possible use similar readings, but will still be essentially different.

Human translation is still too expensive at the moment, but so is joint course development of this kind. The alternative is machine translation. While it does not provide perfect translation, it currently speeds up the translation by humans by 50%, and it is expected to increase in speed and accuracy within five years to the point where it speeds up human translation by 80%.

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The importance of these new developments is not in their individuality but in their combined effects. The trend is all in the same direction: more powerful and cheaper technologies, wider access, and increased integration and convergence of technologies. This will inevitably increase the potential for educational applications.

In summary, the Web looks like it is becoming the dominant educational technology of the future as bandwidth increases and other technologies converge onto the Web. At the same

time, it is necessary to be cautious. As bandwidth and access increases, so will the applications. The Information Highway may be subject to the same gridlock as vehicle highways: the more capacity, the more the capacity gets filled. Even more importantly though, the technology is changing more rapidly than our abilities as humans to accommodate it.

Driving and Constraining Forces of the Emerging Technologies

DRIVING FORCES

Education has never determined technological development, but always followed it. Technology is developed either for purposes of war or for business applications, and educational applications of emerging technology have followed on the coat-tails of military and business applications.

It is clear that for reasons other than education, in developed countries there is going to be increased and continuing investment in the Internet and its underlying infrastructure by governments, businesses and individuals. This investment is being made to develop and maintain a new form of economy based on knowledge and information. These new businesses will be seeking new markets.

Globalisation then — the desire for free trade and open markets — is likely to lead to increased pressure on developing countries to invest in the Internet and telecommunications infrastructure for business reasons. However, it is also critical for educational applications of the Internet that the technical infrastructure be in place. Educational applications of the Internet fundamentally depend on stable electricity provision, stable telecommunications networks, and a stable human resource capacity to build and maintain this technical infrastructure.

A second significant driving force for e-learning is the belief by corporations and investment banks such as Merrill Lynch that this is an area where a great deal of money can be made. Huge sums are being invested in e-learning initiatives. While many mistakes have been made, it is likely that sooner rather than later some corporation will develop a sustainable e-learning business.

Another pressure on educational institutions to use ICT is coming from governments and the business community. They want technology-ready workers for the new economy, and they often believe — wrongly, we shall see — that investment in technology will lead to reduced costs in education.

At the same time, a major driver of the application of learning technologies is coming from within the education community itself (Rowley et al., 1999). In those jurisdictions that saw major cuts in educational expenditures or increased student enrolments without balancing public investment over the last 10 years, teachers have seen their class sizes increasing, and hence their interaction with students diminishing. Web-based learning provides a hope for increased student interaction and access to resources that can free up the teacher's time for more direct contact with individual students.

Finally, another driver for change, and one that will become more significant as time goes on, will be the students themselves. Many students now entering universities and colleges have lived all their lives in a computer-based society. They have been playing computer games, using the Internet to listen to popular music and using mobile phone technology to communicate with their friends. Increasingly, they are expecting their educational institutions to “get with it.”

CONSTRAINING FORCES

Despite the very strong pressures on educational institutions to use ICT, there are other strong pressures that limit its use. Perhaps the most important and least appreciated is the newness of

the phenomenon. The World Wide Web did not exist as a public service before 1990. The first Web-based educational course did not appear until 1995. It should be remembered that it took 50 years after the first book produced by the Gutenberg press before someone hit on the idea of numbering pages. It was over 200 years later before the University of Paris allowed students access to its library. (It had resisted on the grounds that student access to books would undermine the authority of the teacher and intellectual creativity developed through oral debate.) We should not be surprised then that the Web has not revolutionised education in six years.

The Web and the Internet are disruptive technologies (Christensen, 1997). They require a fundamental rethinking of teaching practice. Students no longer are required to be at a set time and a set place to learn. Teachers are no longer the gatekeepers of knowledge. At the same time, schools, colleges and universities play a much wider role than merely transmitting information from one generation to another. They have social and cultural roles as well. Therefore educators are right to be cautious before rushing to adopt the latest technology. Education needs to match the needs of learners. Technology should be used only if and when it contributes to those needs.

Secondly, any move towards using new technologies requires significant up-front technical investment, even if for other commercial reasons the basic national infrastructure already is in place. Servers are required, computers need to be made available in classrooms, networks connected, software installed, and the technology needs to be maintained and upgraded to allow for technological change. Most public institutions, even in the richest developed countries, are under-invested in this area. As a consequence, the technology is often not conveniently available, is unreliable and requires a high level of competence and skills on the part of the teacher and often the students to use. Ironically, the inefficiencies caused

by under-investment often cost more than properly investing in the first place. Nevertheless, even a well-planned investment requires initial additional spending from government and/or the institutions (Bates, 2000).

Thirdly, most institutions have not provided adequate support and training for teachers to use the technology appropriately in an educational setting. As well as technical support, teachers need help with media production and instructional design. Without this, the use of technology is just bolted onto existing practice. As a result it increases not only the teacher's workload but also the students', for marginal results.

Lastly, because the application of the Web to teaching is so new, there are very few convincing research and evaluation studies that indicate clear educational benefits for such an investment. Evidence is beginning to emerge, though, and the picture is not entirely positive. Studies on online learning by Bartolic and Bates (1999), for instance, have indicated the following:

- Online learning provides the opportunity to reach out to new markets, particularly life-long learners and international students.
- The flexibility of online learning is clearly of great value to many mature adults trying to balance work, family and study requirements.
- Many learners seem to appreciate the advantages of international courses and the opportunity to work collaboratively and closely with colleagues around the world and to have access not only to the course instructors, but to textbook authors and experts from other institutions.
- The opportunity to widen the range of potential students through online learning can make sustainable programmes struggling with small enrolments locally.
- Online learning brings major benefits through the ability to work collaboratively with students from several different countries.

- Online learning can be as cost-effective as face-to-face teaching in the right circumstances, but it is not suitable for all students or all kinds of teaching.
- Online learning can be more than cost-effective; it can actually bring in net profits for an educational institution. However, this requires a different approach to the development and management of teaching: it requires financial systems and financial management that, frankly, few higher education institutions have in place or are even ready to contemplate.
- There is a need for substantial start-up funds.
- Faculty require additional time to learn how to use these new technologies and students also have to learn to study effectively online.
- Students need to be psychologically ready and financially able to embrace this method of course delivery.

Studies funded by the Alfred P. Sloan Foundation (www.sloan.org/programs/edu_asynchronous.htm) found that:

Asynchronous learning networks [online learning] as a medium works about as well as the ordinary classroom. Our projects seem to show a slight advantage for online learning and this message comes through from all our projects, but most clearly from the longer running projects such as State University of New York, Northern Virginia Community College, Drexel, and New Jersey Institute of Technology, where extensive teaching experience has been accumulated. The findings of these institutions are based on surveys, test and project results. However the general history of attempts to study the learning effectiveness of various media is that the medium is rarely the issue, it is the pedagogy that matters. Good and bad results can be produced by good and bad teaching. So our own more

conservative view is that the medium works and it is up to the instructor to determine the outcome.

In short, there are important educational benefits to be had from the use of ICT in education. However, for these benefits to be achieved, a major effort is needed to provide suitable levels of investment, adequate training and a restructuring of the teaching process.

Policy Issues for Education Leaders

The issue for developing countries is not one of direction but of readiness and scale. At what point should a nation start investing in educational applications of the Internet? The short answer is immediately, but not for everyone.

If the Internet represents a significant element of the future of education, the sooner that a nation or an educational system gains experience and practice in online learning, the more economically competitive that nation is likely to become. The reverse is also true: ignoring the impact of ICT on education could substantially reduce a nation's ability to compete economically in the 21st century.

However, few developing countries have the resources, the technology infrastructure or the skilled workforce necessary to make online learning available on a wide scale, at least for many years. When resources are scarce, they need to be concentrated and very carefully focused.

It becomes then a matter of timing and priorities. We shall see that the decision to move to virtual education should to some extent depend on economic as well as educational goals.

TRADITIONAL SCHOOLS, OPEN UNIVERSITIES OR VIRTUAL EDUCATION?

One major issue is the balance between investment in the newer forms of ICT, and in particular in online learning, compared with investment

in either traditional school or campus-based education, or older communications technologies, such as print and broadcasting.

Studies by Rumble (1997) and others have shown that the economies of scale of the mass media-based open universities, using print and broadcasting, offer considerable cost and sometimes quality advantages over conventional education. These cost advantages are not so apparent with high-quality virtual education.

The big difference between virtual universities and open universities is the direct interaction between the instructor and the students in virtual universities, leading to more individualised instruction. This, though, comes at a cost. Although there are some economies of scale compared with conventional education, virtual education requires a reasonable student-teacher ratio to avoid instructors becoming swamped with e-mail and discussion forum messages. What virtual education is offering is a more interactive education encouraging critical thinking, communication skills and flexibility for both students and teachers, compared with the one-way mass media of open universities.

For countries with large numbers of students unable to access the later years of secondary or higher education, the open university, mass media model is likely to be the most appropriate, particularly if the aim is to develop a mass skilled workforce able to work in industrial or resource-based industries. Open universities such as Indira Gandhi National Open University, therefore, still provide the best route for mass education (see Daniel, 1996 for further development of this argument).

For countries with already reasonable access to secondary and higher education, and a reasonable ICT infrastructure, virtual education will provide advantages over both conventional and open universities. These advantages will increase particularly for those countries wishing to move

into a knowledge-based economy, but where there is a shortage of teachers in the new economy, since students can access such learning from anywhere in the world.

INFRASTRUCTURE OR EDUCATION?

Virtual education is heavily dependent on appropriate technological infrastructure already being in place for commercial or administrative reasons. Stable electricity supply and reliable and moderately priced Internet access is a necessary condition for virtual learning.

Few institutions or governments have made the necessary investment in infrastructure for educational reasons alone. While in North America the university sector initially developed the Internet, its rapid growth has been driven primarily by the business sector, although government policy can ensure more equitable access.

Government can certainly develop policies that will encourage rapid growth of the Internet, as follows:

- Deregulation of telecommunications services.
- Encouraging competition between telecommunications suppliers.
- Bulk buying of government telecommunications services (e.g., telecommunications services for all public educational institutions) through competitive bidding from suppliers.
- Encouraging Internet use through consortia of educational institutions developing and sharing virtual education materials and courses.
- Careful regulation to ensure access to all (e.g., by making it a condition of licensing that user fees are averaged between urban and rural clients).
- Offering tax breaks to infrastructure suppliers to encourage investment and/or offering tax breaks on computers and Internet services to end users to encourage greater use.

- Supporting open and corruption-free licensing practices to encourage genuine competition.

Some governments decided to invest heavily themselves in the basic infrastructure because of lack of investment by the private sector. For these governments — for all governments — the trick is to know when to open up the management of Internet services to the private sector once a market has been created.

However, until there is a basic and reliable Internet infrastructure in place, connecting at a minimum to most key businesses and universities, virtual education is unlikely to be a realistic or practical choice.

THE NEED FOR TRAINING FOR VIRTUAL EDUCATION

Even if the infrastructure is in place, there must be a national capacity to supply the necessary trained people to support and sustain virtual education. As well as having people who can install, manage and maintain the necessary technical infrastructure, virtual education also needs skilled media producers, such as Web designers and instructional designers.

Unfortunately, there is a global shortage of people with these skills. The danger is that a country will provide the necessary training, then the learners will emigrate to countries able to pay more for their services. Nevertheless, without such a skilled workforce to support it, virtual education will not work.

DEVELOPING A MINIMAL VIRTUAL EDUCATION STRATEGY

Even the poorest countries probably cannot afford to ignore totally the potential of virtual education. At the very least, a country's leaders need to be computer literate, to know how to use and navigate the Internet and to understand not just the technology but its importance for national

development. The minimum, then, most countries should do is to ensure that key government offices, businesses and universities have Internet access.

The role of the university in particular is important. A prestigious national university can provide a model of the benefits and services available through the Internet and develop at least an elite with the skills needed to service national technical and educational needs for ICT development and for virtual education. This will enable the nation to build an affordable and targeted technology infrastructure, to participate in regional collaborative projects, to develop partnerships with institutions in other countries, to identify and adapt suitable programmes from other countries and to develop its own programmes where appropriate.

Conclusion

It is clear that ICT capacity will continue to expand at a rapid rate throughout the world. This expansion will be driven primarily for commercial purposes, but it will also provide the opportunity for economically important educational opportunities. Probably no country can afford to ignore this development.

However, virtual education requires a very stringent set of conditions for it to work successfully. For these conditions to be met, there is a high cost in terms of investment and training. Most importantly of all, the technological infrastructure must be in place. While the technology underpinning virtual education is developing rapidly, the most valuable developments for poorer countries are not yet commercially available or developed.

Virtual education is not the answer to many of the most pressing educational problems faced, particularly by poorer developing nations. Other strategies, such as open universities, can provide greater access and more cost-effective delivery of education.

Governments can do much to encourage the right environment for virtual education. Indeed, governments cannot afford *not* to expose at least a minimum number of its nationals to the benefits of virtual education. The poorer the country, the more focused its efforts to support virtual education will need to be. Partnership with more developed countries, collaboration between countries with similar cultures and stages of economic development and well-targeted, small-scale projects will all help develop capacity and skills in virtual education.

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