The document in front of you is the first on-line version of the original contribution to UNESCO's World Communication and Information Report1999 written by Prof C. Blurton from the University of Hong Kong. In the final form it will be significantly reduced in size. Especially because of the many interesting references we decided to provide the full document on-line. The many interesting references to web-sites appearing in this text are not yet verified, nor directly clickable. We are working on these issues.

New Directions of ICT-Use in Education

INTRODUCTION

Information and communications technologies (ICT) are a diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information. Communication and information are at the very heart of the educational process, consequently ICT-use in education has a long history. ICT has played an educational role in formal and non-formal settings, in programs provided by governmental agencies, public and private educational institutions, for-profit corporations and non-profit groups, and secular and religious communities.

Much has been written about the use of film, radio, telephones, and television in education, (cf., Cuban, 1986; De Korte, 1967; Molnar, 1997). Because access to digital tools, applications, and networks continues to grow worldwide and media are increasingly available in digital form, ICT-use in education can be expected to increase dramatically.

Our Focus

As noted in the *World Education Report* (UNESCO, 1998a), education worldwide is facing a significant challenge in preparing students and teachers for "our future 'knowledge-based' society" during a time when most teachers are not prepared to use ICT and "the majority of existing school buildings, even in the most developed countries, are not equipped to integrate the new information and communication technologies."

In this chapter, we focus on "new" digital ICTs with special emphasis on educational uses of the Internet and the World Wide Web. In our discussion, we will consider several important issues in respect to the use of ICTs in educational settings including how newer ICTs differ from older technologies, why these differences are thought to be educationally important, what research shows about the effectiveness of ICTs in education, what measures are being taken to create ICT-enabled learning environments, and some of the significant issues facing educators and policy-makers when considering implementing ICT. Although our focus will be on formal education, we will also refer to the use of ICT in non-formal and informal education. Along the way, we will provide a few of the innumerable possible examples of current educational ICT applications. We hope to illuminate trends that will help readers to understand current directions and promising practices in the application of these systems in educational settings.

However, although digital ICTs are quickly becoming more accessible, it is important to note that earlier ICTs continue to play a critical role in education worldwide. Access to films, videotapes, telephones, television or radio is still far more commonplace than access to a computer or the Internet and World Wide Web. For example, the *Telesecundaria Project* in Mexico, which began in 1965 as a closed-circuit pilot project, today delivers classes designed for lower secondary school level to over 12,000 rural communities enrolling more than 800,000 students. The Mexican government plans to open an additional 4,500 Telesecundaria schools enrolling 250,000 more students between 1998 and 2002 (Calderoni, 1998). The *Gobi Women's Project* is using radio to deliver instruction including livestock rearing techniques, family care, income generation, and basic business skills to 15,000 nomadic women in Mongolia (UNESCO/UNICEF, 1997a). And, according to a World Bank Report, the China TV University system enrolls over half a million students in degree programs and graduates over 100,000 per year (Potashnik & Capper, 1998).

The new digital ICTs are not single technologies but combinations of hardware, software, media, and delivery systems. Today, ICT in education encompasses a great range of rapidly evolving technologies such as desktop, notebook, and handheld computers; digital cameras; local area networking; the Internet and the World Wide Web; CD-ROMs and DVDs; and applications such as word processors, spreadsheets, tutorials, simulations, electronic mail (email), digital libraries, computer-mediated conferencing, videoconferencing, and virtual reality.

It should also be noted that use of newer ICTs is being integrated with use of older technologies. For example, it is not uncommon to find textbooks sold with CD-ROMs containing multimedia materials or links to related websites (cf. http://www.mmhschool.com/teach/socialstud/socstu1.html). An exhaustive review of all of these technologies, combinations of technologies, and applications is not possible here.

We also acknowledge the difficulties in implementing such innovations, and we are sensitive to the fact that whatever is said now about ICTs in education will quickly become outdated as the technologies and educational applications continue to rapidly evolve.

Changes in Communications and Information Industries

Our emphasis on digital ICT tools and applications in education mirrors profound structural changes occurring worldwide in communications and information industries. The ability to digitize analog signals and transmit them over telecommunications networks is resulting in the restructuring of the radio, telephone, television, publishing, entertainment, and computer industries into new multimedia industries that create digital products combining voice, video, text, graphics, images, and animations, and deliver these signals electronically (Bane, Bradley, & Collins, 1995).

An example of this trend can be found in Hong Kong where New World Telephone is installing "PowerPhones" from which users may read or send electronic mail, send a fax, search online multimedia directories about hotels and tourist spots, and make a telephone call (South China Morning Post, 1998). Another example is Internet "telephony" software that now makes it possible to place domestic and international calls from a computer to any telephone anywhere in the world (cf. http://www.net2phone.com/ telephone.html).

ICT Access Worldwide

Our emphasis also mirrors the increasing access to digital tools and resources worldwide. Although estimating the number of people with Internet access is difficult at best, one current estimate places the total number at around 150 million in late 1998, an increase of over 60% since early 1997 (Nua Internet Surveys, 1998). Internet access is at present strongly concentrated in a small number of countries, providing services to a fraction of the world's population: over 90% of Internet hosts are located in the world's richest 29 counties (Cukier, 1998).

However, this may be expected to change over time as telecommunications costs continue to drop precipitously and governments deregulate access. For example, the number of Internet users in India is expected to climb from half a million in 1998 to 1.5 million by the year 2000 (Rao, 1998). In Africa, it is estimated that there currently are between 800,000 and 1 million Internet users. The current ratio of Internet users to people in Africa is estimated to be one for every 5,000 compared to a world average of about one Internet user to every 40 people. But here, too, the situation is rapidly changing. In 1996, only 16 countries in Africa had Internet access. Now, 53 (three-fourths) of the capital cities are online and the rest will soon follow. A number of international infrastructure building initiatives are underway on the continent including the United Nations Secretary General’s programme *Harnessing Information Technology for Development* that will substantially improve the Internet infrastructure by the year 2000 (Jensen, 1998a). The Russian Non-Profit Center for Internet Technologies estimates that there are now about 1 million Russians online and that this number is doubling every year (http://www.rocit.ru). And, in the next two years, the number of Internet users in Latin America is expected to grow from 8.5 million to about 34 million. The number of Latin American websites, most of which are operated by businesses, could triple in the next year to over 500,000 (Smith, Malkin, Katz, & DeGeorge, 1998). In Asia, estimates place the total number of Chinese online in Hong Kong, Taiwan, and Singapore at 2.6 million (Global Reach, 1998). The number of users in China almost doubled (620,000 – 1.175 million) from late 1997 to mid-June, 1998 (Williams, 1998). Some estimates predict there will be 20 million Internet users in China by the year 2000 (Ramo, 1998).

As these few examples help illustrate, although ICT access is still chiefly available to citizens of developed countries; such access is fast becoming possible in developing countries worldwide.

ICT Access in Formal Education

Although no comprehensive data on ICT in schools worldwide apparently exists, it is clear from many national examples that schools are also increasingly being equipped with ICT.[1] It is also apparent that ICT equipment and Internet connectivity is still much more abundant in North American schools than elsewhere (Genius Newsletter, 1997a).

In the United States, the ratio of students per computer dropped from 63:1 to 6:1 from 1985 to 1997 (Market Data Retrieval, 1998) while the number of schools with internet access has grown from 35% in 1994 (U.S. National Center for Education Statistics, 1996) to 72% in 1997 (QED's Educational Technology Trends, 1997).

In Africa, the *Creating Learning Networks for African Teachers* project, part of the UN's *Harnessing Information Technology for Development* initiative mentioned above, will equip a maximum of four teacher training colleges (TTCs) in each of 20 African countries with a computer and full access to the Internet. The project will also fund teacher training curriculum development and the creation of 20 national educational WWW sites (UNESCO, 1998).

In Europe, more than 80% of schools in Solvenia have access to the Internet – 93% of secondary schools and 80% of primary schools – which is similar to the percentages of developed countries. Nearly two-thirds of secondary schools have a website (Research Internet in Slovenia, 1998). In the United Kingdom, the pupil to computer ratio is 16:1 in primary schools and 9:1 in secondary schools, while 43% of schools in the United Kingdom are connected to the Internet (British Educational Suppliers Association, 1998). The British Government plans to connect all schools, colleges, universities, libraries, and as many community centers as possible to the Internet by 2002 (United Kingdom Department for Education and Employment, 1997). In Germany, the *Schulen ans Netz* initiative (http://www.san-ev.de) begun in 1996, will connect 10,000 schools to the Internet by mid-1999. As of late 1997, of approximately 6,500 were connected and 1,700 had their own website (Schulen ans Netz, 1997). And in Italy, a national program in 1995 resulted in 120 schools being supplied with multimedia equipment. Last year, plans were announced for the installation of computer and multimedia facilities in 15,000 Italian schools to be carried out by the year 2000. At the end of the programme, approximately 25% of all Italian state schools will have access to on-line facilities and the Internet and will be equipped with advanced hardware and multimedia educational software (Genius Newsletter, 1997b).

In Asia, similar developments are taking place. In Japan, as of 1997, over 94% of pubic schools were computer-equipped and 10% were connected to the Internet. The Government plans to provide a pupil to computer ratio of 2:1 in middle schools and 1:1 in high schools by 1999. All of the public schools in Japan will be connected to the Internet by 2003 (Sekiguchi, 1998). In the People's Republic of China, the central government will increase funding for basic, vocational and higher education projects over the next two years. These plans include strategies to make increasing use of Internet-based educational programs (Ning, 1998)

In South America, in 1993, the Chilean government established the *Enlaces* (Links) project to connect schools and related institutions to Chile's national computer network. By 1996, over180 primary schools and 62 secondary schools had been connected and, by the year 2000, the Chilean government plans to have 50% of the 8,250 primary schools and 100% of the 1,700 secondary schools connected. The *Enlaces* initiative also includes equipping schools with computers and a combination of locally produced educational software and commercial products that are available in Spanish language versions (Potashnik, 1996).

In New Zealand,

These few examples serve to illustrate that efforts to provide ICT and Internet access to teachers and students in developed and developing countries around the world can be expected to continue and accelerate until most, if not all, schools are equipped and connected in the next century.

ICT Access in Informal and Non-Formal Education

Informal and non-formal education refers to educational activities and programs that are offered outside of formal educational institutions, including those offered by libraries, museums, community schools and centers, zoos, planetariums, commercial companies, and many other organizations. Informal and non-formal education institutions, too, are increasingly being equipped with ICT and connected to the Internet. At present, about 20% of libraries in the United Kingdom are connected to the Internet. The British government's *National Grid for Learning* initiative will connect all British libraries and museums to the Internet (United Kingdom Department for Education and Employment, 1997). In the United States, a 1998 survey sponsored by the American Library Association found 73% of the nation's public libraries offered basic Internet access to the public (American Library Association, 1998).

Many public and privately funded museums are offering ICT-based learning opportunities. For example, the Computer Museum's website (http://www.tcm.org) offers activities designed to help individuals learn about computers. The British Natural History Museum, as part of a European Union funded project to enable multimedia applications such as virtual museums and galleries to be accessed from remote locations, has constructed a virtual model of the Endeavour, Captain Cook's (an English explorer) ship. The ship, as well as virtual reality objects of seabirds and other animals encountered by Cooke on his voyages (http://www.nhm.ac.uk/VRendeavour/ index.htm), are available on the Web. And, in a joint project with the Fraunhofer Institute for Software and Systems Engineering, the German Historical Museum in Berlin and the Haus der Geschichte of the Federal Republic of Germany in Bonn are developing a virtual exhibition of German history for the Internet (Nentwig, Manhart, Kampa, Wendt, Asmuss, Roehrig & Schneemelcher, 1998).

Community school efforts, too, are increasingly making use of ICTs. The *Lighthouse Project* (el. http://www.media.mit.edu/projects/lighthouse) in Thailand is offering non-formal educational programs at five locations in Thailand as well as an online "community magazine," *Sakura Press*. The community school-based project "initiates a challenge against the existing educational system … The new environments and new technologies will be the main mechanism to help learners generate their own ideas, expand them, and share them with others" (lcs. http://www.media.mit.edu/groups/el/thai/LightHouse/Lampang/ lp_index.html).

In conclusion, ICTs are rapidly becoming available for use in every setting. This trend is true for formal, informal, and non-formal teaching and learning programs. However, such access is much more common among the rich, and in the developed countries, than for the poor, or in developing countries.

POWERFUL DIFFERENCES

In part, efforts to connect educational organizations to the Internet are being driven by societal pressure. But such efforts are also being driven from within education by powerful differences between older and new ICTs, differences that greatly enhance the usefulness of such technologies to teaching and learning. New ICTs differ in several important dimensions from older technologies, including the integration of multiple media, interactivity, flexibility of use, and connectivity. Understanding these differences will provide a clearer picture of why the use of ICT in education can be expected to continue to grow.

Integration of Multiple Media

Because of advances in digital technologies, it is now possible to integrate multiple media into single educational applications. Multimedia applications on CD-ROMs and websites may incorporate text, pictures, audio, graphics, animations, simulations, full-motion video, and links to other software or websites greatly enriching the learning experience.

For example, *Astronomy Village: Investigating the Universe* is a CDROM-based multimedia program developed at the NASA Classroom of the Future (http://www.cotf.edu) that contains ten complete four-week-long investigations for secondary students. Multimedia tools available on the CD-ROM include an image-processing program, an image browser, a telecommunications program for accessing the World Wide Web, a star life cycle simulator, an orbital simulator, and a 3-D star simulator. Multimedia resources include 85 minutes of digitized video clips; more than 300 images from the Hubble Space Telescope and other instruments; 12 illustrated audio lectures by astronomers discussing their work; over 100 computer animations and graphics; and 180 full text documents such as book chapters, NASA publications, and articles from astronomy journals and magazines.

Interactivity

Earlier technologies used for instruction were passive in nature. That is, the delivery of instruction required no action on the part of students beyond listening, watching, and perhaps taking notes. Such ICTs were one-way channels of instructional delivery. New ICTs give the student and teacher the ability to control, manipulation, and contribute to the information environment. On the lowest and least valuable level, this may simply mean the student controls the pace and order of a presentation. But much more is possible. Using ICT students may not only make choices about the pace and order of a presentation, but may choose topics; take notes; answer questions; explore virtual landscapes; enter, draw or chart data; run simulated experiments; create and manipulate images; make their own multimedia presentations, communicate with others, and more (Aldrich, Rogers, & Scaife, 1998).

Flexibility of Use

Previously, ICT-use required students to be grouped together in a controlled environment at a specific time and location. With some technologies, for example radio and television, use was rigidly tied to schedules developed by people far removed from the day-to-day functioning of the classroom. New ICT applications have given rise to the term “anytime-anyplace,” a reflection of the flexibility possible in using ICT to support teaching and learning.

One outgrowth of this flexibility has been the development of “virtual” educational experiences. A virtual experience refers to educational situations in which distance and time separate the teacher and students, who use ICT to interactively to share resources, communicate, and learn. Virtual education allows students to study at their own time, place and pace. In essence, a virtual education means having educational transactions accessible from the home, workplace, or anywhere that the student chooses to be. Virtual classrooms, schools, colleges, and universities offering classes by email, computer-mediated conferencing (CMC), videoconferencing, or websites, or combinations of these technologies, are proliferating. We will say more about virtual education later.

Connectivity

Perhaps the most powerful feature of new ICTs is connectivity. Prior to the 1990s, computers in educational settings were seldom connected to local area networks (LANs) or the Internet. With the widespread adoption of LANs, decreasing telecommunications costs, increasing bandwidth, and the invention of the World Wide Web, educational access to the Internet is becoming commonplace. If equipped with a computer, appropriate software, and Internet access, students and teachers have access to every other person on the planet who has an Internet account, hundreds of thousands of information archives, and millions of webpages of educationally relevant content (cf. http://www.classroom.net/grades).

These four dimensions – integration of multiple media, interactivity, flexibility of use, and connectivity – distinguish digital ICT from previous technologies. Because of these differences, educators are finding powerful new ways to integrate digital ICTs into the curricula.

EFFECTIVENESS

Perhaps the most important question about ICT is how effective is its use in education? To answer this question one must consider three aspects. How effective is ICT-mediated instruction when compared to traditional face-to-face instruction? What does ICT enable that would not otherwise be possible? And third, are ICT worth their costs?

ICT-Mediated Instruction

The first question to be considered about the effectiveness of ICT in education is what, if any, impact ICT-mediated instruction has on student performance. ICT-mediated instruction refers to instruction delivered via a technological channel such as television, radio, or a computer and network.

ICT-mediated instruction can be synchronous, with both the instructor and the student participating simultaneously. For example, instruction may be delivered via desktop videoconferencing by a teacher located at a university to employees at widely separated companies. ICT-mediated instruction may also be delivered asynchronously, with the instructor and student participating at different times. Instruction based on teaching materials placed on a website does not requiring simultaneous participation. Or synchronicity may not matter, as when self-contained instructional materials are packaged on a CD-ROM. In this case, the instructional designer may have developed the materials months or even years before the student uses them and communication between the two is impossible.

Early studies of ICT-mediated instruction's effect on student learning have been characterized as the "no significant difference" phenomena (cf. http://www2.ncsu.edu/oit/nsdsplit.htm). That is to say, whatever medium of instructional delivery – film, radio, television, telephone, or computer – was used, no significant difference on performance measures was found between students receiving ICT-mediated instruction and those receiving traditional face-to-face instruction in a classroom. Both groups perform equally well.

Studies focusing on the use of computer-mediated instruction conducted in the 1980s found more positive results. In a meta-analysis of over 500 individual studies, James Kulik (1994) found:

> 1. Students usually learn more in classes in which they receive computer-based instruction …
> 2. Students learn their lessons in less time with computer-based instruction …
> 3. Students also like their classes more when they receive computer help in them …
> 4. Students develop more positive attitudes toward computers when they receive help from them in school …
> 5. Computers do not, however, have positive effects in every area in which they were studied. The average effect of computer-based instruction in 34 studies of attitude toward subject matter was near zero … (as cited in Glennan & Melmed, chap. 2, 1995)

Kulik's meta-analyses were conducted on studies of computer use prior to the 1990s. Such use was often limited to drill and practice and tutorial software programs. In the 1990s, use of ICT in schools is moving toward engaging students in "authentic" learning tasks in which students use computers, software, and network access to simulate events, communicate, collaborate, analyze data and access information resources. For these applications of ICT in schools, the research data are less extensive. However, some individual studies have been conducted that demonstrate positive learning and affective outcomes (cf., Means and Olson, 1995; Software Publishers Association, 1995; and Special Issue on Educational Technologies: Current Trends and Future Directions, 1994).

A recent study by ETS (1998) of student achievement in mathematics and the use of ICT – the first such study to document relationships between student use of technology across the United States and higher scores on a national standardized test – concluded that "technology does matter to academic achievement, with the important caveat that whether it matters depends upon how it is used" (chp. 4). In another recent study undertaken by the Bertelsmann Foundation (http://www.stiftung.bertelsmann.de) of students in a German school and a school in the United States concluded "that the use of media and technology improves learning outcomes, instills key qualifications for the information age, and increases motivation" (Bertelsmann Foundation, 1998).

And finally, one concern often expressed about ICT is that its use will isolate students from each other and from their teachers. In a 10-year longitudinal study undertaken by Apple Computer, "Dispelling widespread myths, the researchers found that instead of isolating students, access to technology actually encouraged them to collaborate more than in traditional classrooms. And instead of becoming boring with use, technology was even more interesting to students as they began using it for creating and communicating" (Apple Computer, Inc., 1995). It appears, therefore, that ICT, properly used, may enhance and increase communications between people.

In conclusion, evidence has consistently shown ICT-mediated instruction using conventional teaching methods is as good as traditional face-to-face instruction and, in the case of computer-based instruction, may in select instances improve student learning and attitudes towards learning. However, the picture is less clear – but promising – for more sophisticated uses of ICT in the classroom, especially for the host of applications and methods that support "constructivist" learning, in which students are encouraged to work in rich environments of information and experience to build their own understandings about them. Worldwide, research into the effectiveness of ICT-mediated instruction is continuing and should provide a clearer picture of the effectiveness of ICT in supporting constructivist pedagogy. For example, as part of the *Helsinki 2000* project, Finnish investigators are conducting a five-year, multi-disciplinary investigation focused on analyzing innovative pedagogical practices through intensive case studies on computer-supported collaborative learning (Hakkarainen, Halinen, Lipponen, Momaki, & Lehtinen, 1999).

ICT-Enabled Education

A second way to assess the merit of ITC-use in education is to consider what, if anything, such use enables students and teachers to do that they would not otherwise be able to do. To explore this question, we consider five aspects of the educational use of ICT – supporting new pedagogical methods, accessing remote resources, enabling collaboration, extending educational programs, and developing skills for the workplace.

Supporting New Pedagogical Methods

Modern constructivist educational theory emphasizes critical thinking, problem solving, "authentic" learning experiences, social negotiation of knowledge, and collaboration – pedagogical methods that change the role of the teacher from disseminator of information to learning facilitator, helping students as they actively engage with information and materials to construct their own understandings. That is, students learn *how* to learn, not just *what* to learn (cf. Forman & Pufall, 1988; Newman, Griffin, and Cole, 1989; Piaget, 1973; Resnick, 1989; Strauss, 1994).

ICT has the potential to be used in support of these new educational methods, as tools enabling students' learning by doing. ICT can make it possible for teachers to engage students in self-paced, self-directed problem-based or constructivist learning experiences; and also test student learning in new, interactive, and engaging ways that may better assess deep understanding of content and processes (cf. Strommen & Lincoln, 1992; U.S. Department of Education, 1993).

Two examples may help illustrate how ICT can support constructivist teaching methods. *Computer Supported Intentional Learning Environments (CSILE)*, developed at the Ontario Institute for Studies in Education, is a network system that provides support for collaborative learning and inquiry within a school. *CSILE* (csile.oise.utoronto.ca/intro.html) promotes student interaction through referencing, connecting ideas, sharing authorship, and "building-on" the work of others to advance knowledge. The central feature of *CSILE* is a "communal" database into which students can enter text and graphics, and can read, add to, and comment on other's work. The commercial version of *CSILE*, *Knowledge Base*, is being used in both work and educational settings in Canada, Japan, the United States, Finland, and the Netherlands.

The *Physics Teaching Studio*, pioneered at the Rensselaer Polytechnic Institute (http://www.ciue.rpi.edu/Studioteaching.html) in the United States, incorporates the systematic use of ICT in a cooperative learning environment for instruction in undergraduate physics. Laboratory data acquisition and analysis tools are embedded into a hypermedia text that introduces scientific topics, links the students to related materials, and poses questions for the students to answer with the ICT tools. Studio courses emphasize a hands-on, learning by doing approach engaging students in various problem solving and active learning sessions (Wilson, 1997). This approach has been applied to mathematics courses and the concept has spread to other universities including City University of Hong Kong (http://www.cityu.edu.hk/mpu/linkage/03-97/e970309.htm) and Curtin University of Technology in Australia (134.7.115.97/teaching/studio/index.html).

Improved assessment tools can also be developed using ICT. Such assessments can engage students in tasks that require data manipulation, simulation or other interactive acts of knowledge construction. VizQuiz is a multimedia program that allows students to take a chemistry quiz at a computer, but with the added advantage that color graphics, animations, and video clips can be included in the questions. In addition to multimedia capability, such programs can provide hints, remedial feedback, worked out solutions or explanations, and instantaneous grading (jchemed.chem.wisc.edu/JCESoft/Issues/ Series_D/3D1/prog1-3D1.html).

However, although ICT offers the opportunity to construct powerful learning experiences, it is pedagogically neutral. That is, instead of being used in the ways described above, ICT can be used in support of traditional teaching methodologies like the large group lecture, student note taking, and examinations (cf. Hunt, 1998). Teachers can use a computer and projector to show slides to illustrate a lecture, students can use laptop computers to take notes during the lecture, and multiple choice quizzes about the content of the lecture can be put on a website. How these new ICT tools and resources will be used is a human decision, not inherent in the technologies themselves.

Accessing Remote Resources

As previously mentioned, connectivity is one of the main differences between older and new ICTs. Below, we discuss two aspects of connectivity – access to material and to human resources.

Historically, information resources at libraries, schools, and universities have only been available within the walls of these institutions, in a wide variety of physical media, at certain times of the day, and in limited quantities. Because of advances in ICT, it is no longer necessary for students and teachers to be at a certain location at a specific time to acquire a physical object. The Internet represents the greatest collection of human knowledge ever assembled, and it is available to every student and teacher properly equipped with ICT. An unlimited number of digital representations of physical objects can now be made available to students at any time and from any place.

Digital library initiatives are being undertaken in countries around the world that will provide collections that are electronically accessible of the Internet including printed works (e.g., textbooks, journals, illustrations, maps, charts and graphs), photographs, films and videotapes, paintings, 3D models, graphics, animations, software, reference materials, audio files, and so forth. A joint effort between the European Union and the National Science Foundation in the United States is exploring international collaboration on research to develop such libraries (Schauble and Smeaton, 1998).

Specialized collections of digital information are also being created. For example, the entire works of William Shakespeare may be accessed, searched, and downloaded from a website at the Massachusetts Institute of Technology (MIT) (the-tech.mit.edu/ Shakespeare/works.html). Web-based language dictionaries (cf. dict.leo.org/dict/ dictionaries.html), such as the *LEO English/German Dictionary* (dict.leo.org/dict), provide a means to translate words and phrases from one language to another. The Louvre Museum's website (mistral.culture.fr/louvre) offers visitors a virtual tour and access to digitized images of major works from its collection. The *NASA Image eXchange* (nix.nasa.gov/nix) offers access to hundreds of thousands of images taken by U.S. spacecraft of the Earth, the planets, moons, asteroids, and other extra-terrestrial bodies.

Thousands of websites now exist that contain collections of high quality curriculum guides, lesson plans, and instructional activities. For example, the United Nations *CyberSchoolBus* website (http://www.un.org/Pubs/CyberSchoolBus) contains teaching units on urbanization, disease, the environment, and women and politics, as well as interactive games, maps, databases, and quizzes. Specialized websites designed to provide information and assistance in specific subject areas are also proliferating. *Lingu@NET* is a website developed by the British government to provide "quality-assured resources for language teachers and learners worldwide" (http://www.becta.org.uk/projects/linguanet/ lingabout.html).

And finally, remote access to expensive scientific instrumentation is also possible. In the United Kingdom, the *Virtual Microscope* (http://www.open.ac.uk/OU/Showcase.html) of the Open University can be used by students to view slides over the Internet (or from a CD-ROM version). The *Hands-On Universe* project (hou.lbl.gov/index.html) at the Lawrence Berkeley National Laboratory, co-funded by several U.S. government agencies, has developed and piloted an educational program that enables high school students to request their own observations from telescopes at professional observatories. Students download digital images to their classroom computers and use powerful image processing software to visualize and analyze their data.

This ability to access remote resources and use them locally, although not without negative aspects (see "Significant Issues"), fundamentally changes the quantity, nature, and potential uses of information resources available for educational purposes. In addition to efforts to digitize existing physical resources, many new information resources (e.g., websites, digital images, electronic journals and newsletters) are being created which can *only* be accessed electronically. As digital representations of physical resources are created, and as more information resources are distributed only in digital format, it will be critical that students and teachers have ICT access.

Enabling Collaboration

Not all resources are inanimate. ICT enables educational collaborations between individuals and groups of people. Such collaborations may take place locally or between people in widely separated geographical locations. They may be temporary or long-term. Students may collaborate with peers in other schools, teachers may collaborate with university professors, members of the local business community may serve as mentors to students, scientists in government agencies may work with school children, and so forth. Only educational usefulness and access to ICT limit the possibilities.

Email, computer-mediated conferencing, and desktop videoconferencing are all being used to support collaboration between individuals and groups. Collaborations are also taking place by means of real-time chat systems (http://www.idiom.co.uk/intchat.htm); whiteboards (http://www.sisweb.com/math/whiteboard/); newsgroups (http://www.peg.apc.org/~iearn/works.htm); computer-mediated conferencing (CMC) (http://www.ascusc.org/jcmc/); and specialized software like *CaMILE: Collaborative and Multimedia Interactive Learning Environment* (http://www.cc.gatech.edu/gvu/edtech/CaMILE.html) and *The Knowledge Integration Environment* (http://www.kie.berkeley.edu/KIE.html). Other applications include MUDs (Multi-User Domains) MOOs (Multi-user domain, Object Oriented), and MUSHs (Multi-User Shared Hallucinations). Such applications are Internet-accessible, text-mediated virtual environments in which participants can both interact with others as well as help construct the common virtual space. At the University of California, Berkeley, classes in language, literature, linguistics, law, and communications are making use of such applications (moolano.berkeley.edu). Combinations of these ICT applications are also frequently used in educational programs.

Online Experts

Many organizations offer “ask an expert” services. For example, students may send inquiries about scientific topics to working scientists at the Canadian Centre for Marine Geology of Dalhousie University (is.dal.ca/~stanet/ask.html) and the U.S. Argonne National Laboratory (newton.dep.anl.gov/#AAS). In other examples, online experts offer advice in health (http://www.goaskalice.columbia.edu/index.html), weather topics, (http://www.kark.com/kark5a.html), and construction engineering (http://www.siue.edu/ENGINEER/CONSTRUCT/conclub.htm). In an extreme example of how ICT can bridge distance to enable students to access remote expertise, last spring students from four universities in the U.S. and Canada and discussed physiology experiments with astronauts orbiting the Earth aboard the space shuttle *Columbia* (Chronicle of Higher Education Online, 1998).

Online Mentors

ICT can also enable mentoring programs to provide one-on-one guidance to individuals by well-established members of a particular community. Such virtual collaborations between individuals are an effective ways for senior members of a community to teach, inspire, and support newcomers. Mentor High School in the United States offers an electronic *Quest Forum* in which freshmen students may discuss course options with students in the senior class (http://www2.mhs.k12.oh.us/quest/forum). In a project intended to increase retention of new teachers in the profession, the U.S. National Science Teachers Association is providing first year elementary teachers with experienced teachers as mentors (live.nsta.org/reports/article2.htm). And in a final example of how ICT can support mentoring,, the Asian American Psychological Association (AAPA) offers an electronic discussion group on which, according to the organization’s president elect Richard Suinn, “the elder researchers are logging on in a very constructive and supportive way, providing information and support to younger researchers” (Murray, 1998).

Virtual Learning Communities

ICT makes it possible to engage people in widely dispersed locations in "virtual learning communities." Virtual learning communities are learning groups based on shared purpose, not artificial distinctions of location or age. Through ICT, learners can be drawn together from almost anywhere, and they can construct their own formal or informal learning groups. Such communities may transverse barriers of time, geography, age, ability, culture, and social status.

ICT that supports such efforts can be as simple as email or as sophisticated as desktop videoconferencing systems. In an example of how email is being used to enable virtual learning communities, a course titled *International E-Mail Debate* is being offered by professors at universities in Turkey, the United States, Germany, and the Czech Republic to promote writing skills across cultures and enhance intercultural awareness. Students enrolled in the course debate position papers on timely and relevant topics using E-mail (http://www.cba.uri.edu/Faculty/Kim/global/ DEBATES.HTM).

Virtual Design Studios, begun in 1993, are collaborations between teams of Architecture students in universities worldwide (arch.hku.hk/projects/vds/). Teachers and students, on different continents and in different time zones, work on a common design project using computer-aided design systems, email, a central database, and video-conferencing. Participants use the World Wide Web to display their designs and a virtual international jury of architects and teachers judges the relative merit of the work. Past student projects included re-designing housing in Shanghai and designing a Center for Cultural and Religious Studies in Japan. A similar effort took place in 1996 between students and teachers at Union College (USA), METU (Turkey), and Queen’s University (Canada) (design.me.metu.edu.tr/vds/). Virtual Design Studio techniques are being utilized by other disciplines, such as Engineering (cf. Sclater, Sclater, & Campbell, 1997).

The *Global Learning and Observations to Benefit the Environment (Globe)* program (http://www.globe.gov), sponsored by the U.S. Government, links students, teachers, and the scientific research community worldwide in a virtual learning community to study the global environment. Internationally, *GLOBE* is being implemented through bilateral agreements between the U.S. government and governments of partner nations. As of December 1998, thousands of schools in 74 countries have registered as participants. In the *GLOBE* program, scientists design protocols for specific measurements they need for Earth Science research that can be performed by K-12 students. Teachers are trained in the *GLOBE* protocols and teach them to their students. Students make the measurements, enter data via the Internet to a central data archive, and the data becomes available to scientists and the general community. Scientific visualizations of the data are provided over the Internet. Students benefit by having a "hands-on" experience in science, math, and technology, using their own local environment as a learning laboratory. Students also benefit from the opportunity to communicate with their peers around the world, thus increasing not only their environmental understanding but also their understanding of other cultures and their sense of global community.

Beginning in 1995, a series of online "Quest" projects have brought together students and teachers together around the world into a virtual community to learn about specific topics framed in an interactive learning expedition. For example, during *MayaQuest*, a 1995-96 project, over 1 million students, teachers, and others from around the globe followed the progress of a five-rider scientific bike expedition among Mayan ruins in Mexico and Central America, learning about the ancient Mayan civilization and learning from on-site archaeologists. The bicyclists carried laptop computers and a satellite dish to connect to the Internet. Students voted on team decisions, explored 21 Maya sites and were virtually on hand for several major archaeological discoveries. The original *MayaQuest* website (no longer available) received over a 1.2 million hits in 90 days. It offered team updates, photographs, teachers' guides, and direct interaction with eight of the world's top archaeologists. The company has since offered educational scientific expeditions to Africa and the Galapagos Islands (africaquest.classroom.com/gqmarket/gqmarket.asp). Other organizations are offering online learning adventures for teachers and students. The *Jason Project* (http://www.jasonproject.org) and the *Magellan Global Adventure* (http://www.adventureonline.com/ga/index.html) are two other examples of such online adventures, explorations, and expeditions.

The *SIMULAB Project*, supported by the European Union, involves web-based communication between language students across national boundaries. Using specialized software, teachers can create Internet-based simulations for role-playing activities in language learning. The simulations, incorporating email, chat, and online creation and editing of documents, are thought to motivate oral and written communication amongst the participating groups, while students are guided through scenarios relevant to the country of their chosen language (http://www2.echo.lu/telematics/education/en/projects/files/ simulab.html).

The UNICEF *Voices of Youth* website (http://www.unicef.org/voy) offers opportunities for teachers and students to participate in discussions on current global issues, such as the effects of war on children; take part in interactive global learning projects, and exchange experiences about the use ICT in education.

Home/School Communications

Although such virtual learning communities can span the globe, they can also be formed locally. For example, in the U.S., students, parents, teachers, and administrators in the Los Angeles Unified School District's *Project REBUILD* have joined together into a virtual learning community with the objective of improving the performance of Limited English Proficient (LEP) students. Staff at 11 schools are using interactive videoconferencing over computer networks to jointly plan lessons and team-teach from different sites. All students in *Project REBUILD* schools, mostly minority children, are provided with access to the Internet and electronic mail in their classrooms and from their homes. Homework assignments are placed on the web and informal parent-teacher conferences take place electronically whenever necessary. Staff members at the school sites receive continuing professional development instruction and consultation via videoconferencing from staff at the Center for Language Minority Education and Research at California State University Long Beach. Among other reported benefits, students in the program have made substantial gains in English reading proficiency (Green, 1998).

In the United Kingdom, Microsoft, Comtel and International Computers Limited (ICL) have funded the *Highdown Information Hub* (http://www.highdown.berks.sch.uk) which connects homes and schools via the Internet. Parents are able to send email to their children at school during the working day, view projects that their children are working on, and electronically converse with teachers, opening up new learning opportunities by enabling close collaboration between parents, students, and teachers.

Extending Educational Programs

ICT makes it possible to extend the reach of educational programs in two important ways. First, ICT makes it possible to deliver educational programs anywhere in the world. Second, ICT also can help individuals learn throughout their lifetime.

Distance (Distributed) Education

Distance education programs, also known as “distributed” education programs, are those in which the teacher and students are physically separated, and teaching and learning takes place by means of single technologies or combinations of ICTs.

In the past, such programs made use of print, radio, and television. Now, new ICTs are driving changes in these traditional “open” or distance education programs. Such programs are increasing using the Internet and the World Wide Web for the delivery of courses. For example, the International Francophone Consortium of Distance and Open Learning Institutions (CIFFAD), a consortium of open and distance learning institutions spread over 49 countries, of which 80% are in developing nations, has recently entered into a phase of reengineering to make use of new ICTs. The group aims to provide at least one hundred access points to the Internet per year in member establishments with the major part of the consortium having access to the network by the end of 1998 (Simard, Lopez, & Fofana, 1998).

In an initiative making use of a combination of virtual and traditional educational programs, Singapore's two leading research universities – the National University of Singapore and Nanyang Technological University – and The Massachusetts Institute of Technology in the U.S. recently signed an agreement to “create a new global model for long-distance engineering education and research” (“MIT and Singapore Launch Global Educational Collaboration,” 1998). The jointly developed degree programs will enroll their first students in July 1999, and will be created and delivered by instructors from the three institutions, using a combination of faculty and student exchanges and state-of-the-art communications technology.

Typically, distance education courses have been offered as supplementary programs by campus-based educational institutions. Now, however, digital ICTs have stimulated the creation of “virtual” non-profit and for-profit educational institutions that exist partially or only in “cyberspace” and whose programs are offered entirely by means of ICT. Such efforts are making it possible for ICT-equipped individuals located anywhere to participate in educational programs.

The Western Governors University (http://www.wgu.edu) is an example of a “virtual university,” a university that has no physical campus. WGU, initiated in 1996 by the governors of 18 of the Western United States, is a competency-based, degree-granting, virtual university: “a ‘cyber’ university that is not bound by its location because it doesn't have a campus in the physical sense. By using the latest technology … WGU is able to bring classes to you, regardless of where you are” (http://www.wgu.edu/wgu/about/ whatwe.html). WGU is currently offering more than 300 college-level distance learning courses from 30 affiliated universities and education providers. WGU has forged international alliances with the China Internet Education Center, Tokai University in Japan (http://www.u-tokai.ac.jp), University of British Columbia in Canada (http://www.ubc.ca); The Open University in the United Kingdom (http://www.open.ac.uk); and the Virtual University of the Monterrey Institute of Technology in Mexico (http://www.sistema.itesm.mx/english/ uv.htm) to collaborate on the development and delivery of distance learning programs. (The Virtual University of the Monterrey Institute of Technology enrolls nearly 70,000 students within Mexico and offers 31 baccalaureate, 37 masters, and 7 doctoral programs.)

In Germany, the four Baden universities Freiburg, Karlsruhe, Mannheim and Heidelberg recently announced the establishment of that country’s first virtual university. The initiative’s objective is to establish individual distance learning via e-mail, ISDN or digital television. Within the next five years, the project will receive financial support of 8.8 million marks from the state of Baden-Wuertemberg within the framework of the "Future Initiative Young Generation" (Die "Virtuelle Universität Oberrhein" [VIROR] bündelt Multimedia-Know-how der Universitäten Freiburg, Heidelberg, Karlsruhe und Mannheim, 1998).

In Africa, the World Bank is funding the development of the African Virtual University (AVU). This effort holds great promise for improving educational access for people on a continent where relatively few enjoy the benefits of education, let alone a tertiary education:

> Very few African countries have attained primary education for all, despite the fact that many have been independent for some thirty years. At secondary level, the record is even worse, with many African countries able to provide secondary education to only 4 or 5 per cent of the age-group. Most African countries can boast of less than 1 per cent of the relevant age-group attaining any form of tertiary education, compared to between 25 per cent and 75 per cent in industrialized countries. And those who do attain tertiary education are unlikely to specialize in science or technology. (International Commission on Education for the Twenty-First Century, 1998, p. 206)

AVU (http://www.avu.org) completed a pilot phase in 1996-98 and is now moving into an operational phase when it will begin delivering full-fledged undergraduate degree programs in Science and Engineering in January1999. The AVU’s programs will be delivered by a combination of ICT including interactive television and the Internet. The program is developing a digital library of scientific engineering as a resource to students and teachers.

Virtual educational programs are not limited to postsecondary education. The U.S. Department of Education has funded the Virtual High School (VHS) project (vhs.concord.org), a collaborative of U.S. high schools that develops and shares web-based courses. During the 1997-98 school year, VHS offered 29 Internet-based, credit-bearing courses to about 500 students in 27 schools located in 10 states. This approach is thought to be particularly useful as many of the participating schools either have no qualified teacher or insufficient enrollment to justify individually offering some of the courses available through the collaborative.

In addition to traditional institutions using ICT to enhance or create distance learning programs, commercial companies like Sylvan Learning Systems, Inc, (http://www.educate.com) in the United States and the Wall Street Institute School of English (http://www.wallstreetinstitute.com) in Europe are starting ICT-based for-profit distance education programs. Although alternate and distance education providers currently make up less than 2% of the postsecondary education market, almost $2 billion dollars has been raised on Wall Street since 1996 to finance such new ventures (Marchese1998).

Lifelong Learning

Unlike in the past when a person's education took place for a specific period of time during their youth, education is now widely seen as a continuing activity taking place throughout the lifespan. Establishing lifelong learning habits among citizens and providing lifelong learning opportunities has become a major goal of government initiatives worldwide (cf. Hatton, 1998).

Lifelong learning is thought to be important for at least two reasons. First, it is no longer possible to master an entire discipline in a few short years. The amount of information available and the speed at which new information is being created makes this impossible. Consider, for example, that printed scientific information doubles approximately every 10 years. Half of all available scientific information has been published in the last 10 years (Odlyzko, 1996). Second, career changes are becoming more frequent as are changing requirements within individual professions. For example, the People's Republic of China is facing changes of unprecedented magnitude in its traditional industries, and a large number of workers are being forced to change careers or take early retirement. In order for these industries to survive and to take advantage of market opportunities, the workforce will need to be upgraded to work at higher knowledge levels with new technology (Wu & Qilian, 1998).

Because ICT can enable teaching and learning from anywhere at anytime, it is seen as an effective means to provide lifelong educational opportunities. In a recent report, the World Bank's Consultative Group on International Agricultural Research (CGIAR) noted:

> In industrialized nations, it is widely recognized that lifelong learning has become essential in a world driven by new science and technologies, with frequent retraining being needed for many professions. Fortunately, we now have a new tool that makes this type of education much more readily possible. The Worldwide Web is being used as a direct teaching tool that allows virtual classrooms of interacting students and faculty to be created through "asynchronous learning networks." (CGIAR System Review Secretariat, 1998)

In another example of how ICT is seen as providing the means of enabling lifelong learning, UNESCO's *Learning Without Frontiers (LWF)* initiative (http://www.unesco.org/education/lwf/), which has sponsored many conferences, policy documents, publications, and pilot projects focused on lifelong learning:

> … is geared towards stimulating innovation and exploring alternative pathways/partners/technologies for the provision of lifelong and lifewide learning opportunities, particularly, to those who are currently unreached by or excluded from conventional modes of educational delivery. As part of this challenge, LWF is concerned with exploring how various technologies and approaches can be used to overcome multiple barriers to learning (i.e., age, time, space, circumstance) and to assist with broader development objectives (UNESCO, 1996).

Many examples of how ICT is being used to foster and encourage lifelong learning can be found. In Africa, *LWF* is supporting the implementation of "Multipurpose Community Telecenters" in five countries (Benin, Mali, Mozambique, Tanzania, and Uganda) at which locals may have affordable access to ICT. By enabling users to share the costs of facilities and support, the Telecentres will offer low-cost means of Internet access as well as information support for literacy campaigns, basic and non-formal education, and information on government programs. The Telecenters will also provide facilities for the generation and exchange of community-based information.

In Great Britain, the Department for Education and Employment (http://www.dfee.gov.uk/dfeehome.htm) has established a "UK Lifelong Learning" website (http://www.lifelonglearning.co.uk) that provides news, reports, and lists of lifelong learning opportunities. Earlier this year, the Dutch government launched a national program for lifelong learning "to ensure that better use is made of the country's intellectual resources." As part of the program, teacher-training colleges will receive extra funding to experiment with ICT (http://www.minocw.nl/english/press/e9802.htm#art4). The European Lifelong Learning Initiative (http://www.ellinet.org/elli/home.html) makes use of ICT, "to initiate the dissemination of information, the co-ordination of projects and studies, the mobilisation of actions, people and organisations to bring Europe into the Lifelong Learning Age. It covers all sectors and all countries" (European Lifelong Learning Initiative, 1997).

The Asia Pacific Economic Cooperation (APEC) Forum has established three mechanisms to assist countries across the area to establish lifelong learning projects: the creation of a database of Asian scholars, researchers and practitioners involved with lifelong learning issues and programming across the region; the development and publication of a book of papers on lifelong learning policies, practices and programs across the Asia Pacific region; and a lifelong learning conference for APEC members to discuss issues identified in the book (http://www.apec-hurdit.org/lifelong-learning-project.html).

Developing Skills for the Workplace

After leaving school to embark on a career, young people can expect the day-to-day practice of every discipline to be affected by the use of ICT. In the future, economic competitiveness, employment, and personal fulfillment may no longer be based on the production of physical goods. Personal and national wealth creation may be linked to the production and dissemination of knowledge and depend on research, education and training, and on the capacity to innovate. Having advanced ICT skills and knowing how to use discipline-specific applications may help students secure suitable employment and enhance their productivity once employed. Furthermore, as has been noted above, the ability to engage in life-long learning opportunities offered by educational institutions around the world is increasingly dependent upon access to, and use of, ICT.

In light of changing perceptions about what constitutes appropriate skills for the modern era, some organizations are promulgating educational standards, attempting to codify what all students should learn about ICT. For example, the National Educational Technology Standards (NETS) project in the United States has released an initial set of national educational technology standards for pre-college students (cnets.iste.org). The NET standards are divided into six categories including “Basic Operations and Concepts,” “Social, Ethical, and Human Issues,” “Technology Productivity Tools,” “Technology Communications Tools,” “Technology Research Tools,” and “Technology Problem-Solving and Decision-Making Tools” (International Society for Technology in Education [ISTE], 1998).

However, although it can be anticipated that the increasing use of ICT in education and society will change the nature of the knowledge and skills students must acquire in order to compete and contribute in an increasingly ICT-dominated global economy, what skills will be necessary is not clear:

> What do students need to know and do with technology? Unlike the more stable content and goals we have for other areas of school study, technology continues to change and evolve; with these changes come ever-new goals for how technology should serve learning, and what students should know about technology. A review of the "prevailing wisdom" about appropriate technology use since the early 1980s takes one down an ever-turning road that includes programming in BASIC, then with LOGO; and on to drill and practice applications on integrated systems; word-processing and curriculum-specific tools like history databases, simulations, and microcomputer-based labs; then multimedia; the Internet; and now Web page design. While there may be some logic to this progression, the reality is that, just as educators get their arms around one approach, with the attendant investments in software, training and possible curricular readjustments, the messages about appropriate technology use change. (Fulton,1998a)

There does seem to be a growing consensus that all students must achieve “Information literacy”: “It is the task of general education to provide every girl and boy with the versatile basic skills in acquiring, managing and communicating information which are necessary in the information society and essential for successful further study” (Ministry of Education, Finland, 1995).

The American Library Association has outlined seven steps representing the basic elements in an information literacy curriculum: Defining the need for information, initiating the search strategy, locating the resources, assessing and comprehending the information, interpreting the information, communication the information, and evaluating the product and process (American Library Association, 1996). Anderson and Bikson (1998), in a discussion of generic skills that “information society literate” citizens should have, suggest three categories into which such skills might be categorized: Connectivity, Logic, and the Structuring of Data and Information.

It is clear that new skills and knowledge will be necessary to compete and contribute in a global "knowledge society." However, because of the rapid pace of change of ICTs, it is less clear what skills can be taught to today's students that will still be relevant by the time they graduate and enter the workforce. Focusing on concepts like "information literacy," rather than on specific technologies or applications, may be essential in planning and developing new curricula.

Cost-Effectiveness

The third issue we consider when assessing the effectiveness of ICT in education is the question of cost-effectiveness – information is of critical importance, especially to developing countries with fewer resources to invest. However, assessing the cost-effectiveness of ICT in education is difficult, if not impossible, for at least four reasons – lack of meaningful data, variability in the implementation of ICTs, difficulty of generalizing from specific programs, and difficulty of assessing the value of qualitative educational differences. In addition, cost-analyses do not consider the societal and economic consequences of *not* investing in ICT for education.

First, direct comparisons between traditional and ICT-based educational programs are hard to make because meaningful data are lacking. When considering the costs associated with ICT use, what variables are included in such studies vary widely. For example, in addition to hardware and software costs such an analysis may or may not take into account factors such as teacher training, support personnel, facilities renovation, security systems, insurance, and so forth. Furthermore, many institutions making use of ICT in their programs simply do not collect such data. Potashnik and Adkins (1996) reported problems in conducting a cost-analysis in developing countries because of the lack of local "effective efforts to do real world cost analysis" and the difficulty "to obtain the kind of information we would have liked to include in our cost analyses" (p. 11).

Second, there is the question of which technologies and applications to compare. The costs associated with any ICT-based educational program may "merely indicate the choices that have been made, not the choices that are possible" (Twigg, 1996). Evaluating the cost-effectiveness of email-based courses will return a different result than comparing courses using videoconferencing technologies, although the educational goals may be similar. Making judgments as to the cost-effectiveness of ICT-use in general from the analysis of particular programs is difficult.

Third, as has been noted earlier, ICTs are not single technologies or applications, but an array of possibilities. Many ICT-based educational programs use a combination of technologies and applications, making the analysis of costs and comparisons with other programs even more difficult. This is further complicated because of the rapid evolution of ICT and changes in its uses in education. Studies typically take a long time to complete and longitudinal studies take years. Such efforts may be doomed to failure because the subject under study is a "moving target."

And finally, there is the question of what metrics are useful in measuring "effectiveness." Is "effectiveness" determined by units of instructional time, by student retention rates, by performance on assessments? Quantitative measures are easier to construct but may not ultimately tell us much. Qualitative differences may ultimately be more important in assessing the cost-effectiveness of ICT, but may not be measurable. For example, approaches to incorporating ICT into education can be roughly grouped into three categories – learning about (computer literacy and programming), learning by (drill and practice and tutorial software), and learning with computers (collaborating with remote groups, conducting research over the Internet). Are all three curricular approaches of equal value?

In more recent years, the third approach, integrating ICT-use throughout the curriculum, has been the focus of reform: "Integrating or integration means that emerging technologies must be interwoven into the total fabric of education to make technology and education one" (Bailey & Lumley, 1994, p.11, as cited in Murphy & Gunter, 1997). But how does one measure this educational goal? What constitutes effective and sufficient integration? Also, how can "cost-effectiveness" of ICT-equipped versus non-ICT-equipped classrooms be assessed when taking into account less tangible benefits like the ability to access remote resources or to collaborate with students in other countries?

Cost Comparisons

None-the-less, even in the face of such obstacles, attempts to establish the relative costs of ICTs in education have been reported. In general, these studies find that the use of new ICTs is more expensive that instruction delivered by older technologies like print and radio, but less expensive than instruction delivered by television. For instance, Potashnik and Capper (1998) reported:

> Print, audiocassettes, and prerecorded instructional television (lectures) are the lowest-cost technologies for small numbers of students (fewer than 250), while radio requires 1,000 students or more to achieve comparable per-student costs. Computer conferencing is a low-cost approach to providing interactivity between teachers and students, but live interactive broadcasts and video conferencing are still very high-cost technologies, regardless of the number of students enrolled. (Potashnik & Capper, 1998)

In a World Bank report (1998) on education and ICT in Latin America and the Caribbean, the costs of using a computer with an Internet connection in a school was much less expensive per pupil than broadcast television, but substantially more expensive than radio.

It should be noted that even these findings may be misleading because of the variability across regions and individual countries in the cost of Internet access and what such costs mean in the real income of individuals in various countries. As should be clear from the information below, although Internet access is absolutely less expensive in Africa than Europe, the "real" cost to individual users in Africa is much higher:

> Currently, the average cost of using the Internet for 5 hours a month in Africa is about $60/month. This contrasts with figures of the Organization for Economic Cooperation and Development (OECD) which estimated recently that 20 hours of Internet access in the U.S. costs $29, including phone and provider fees. Although European charges are more ($74 in Germany, $52 in France, $65 in Britain, and $53

> in Italy) all of these countries have per capita incomes which are 10 - 100 times greater than the African average. (Jensen, 1998b)

"Despite the general lack of cost data that can be used to estimate the cost of information technology projects in developing countries," Potashnik and Adkins (1996) were able to compare the per pupil costs of setting up a computer laboratory in a school for computer-assisted instruction in Belize ($78), Jamaica ($89), and Chile ($104) (pp. 13-15). A similar analysis of the costs of equipping a classroom, not a laboratory, with computers in the United States for computer-assisted instruction yielded a figure of $453.[2] (This difference may be explained by variations in human costs as well as a tendency for the data from developing countries to underestimate some costs associated with operating a computer laboratory.)

Osin (1998), in a paper on ICT in developing countries, assessed the annual per-student cost of providing computers for instruction in developing countries at $84 USD. This finding is in close agreement with the study by Potashnik and Adkins reported above. By extrapolating the expenses if 30 computers were used 300 days per year, 10 hours per day, as a resource to raise the skills and education levels of all members of the community, not just students, Osin estimates the cost drops to 34 cents per hour of interaction. He concludes, "There is no alternative system known that may provide the benefits possible by integrating computers in the education system, while at the same time serving the whole community." (p. 9).

Costs of Alternatives

Another factor that must be considered when calculating the cost-effectiveness of ICT use is the question of alternatives. The costs of building sufficient campuses to handle the rising demand for education may be prohibitive. Virtual educational institutions do not require the same campus infrastructure and related costs traditional campus-based institutions must support:

> The number of places in conventional colleges and universities and school systems will always be limited, reflecting in part the fixed capacities of the campus and the faculty. Developmental and operational costs associated with conventional colleges and universities are high. By comparison, distance education has lower start-up costs, and much lower operational costs. With "campus-free" distance education, variable costs, once the system is operational, tend to be flat. That is, beyond a relatively small number of students, the costs per student are the same or slightly less. The increasing use of technology to broaden the scope of distance education has great potential for further reducing costs per student. In Chinese Taipei, the distance education-based National Open University, with its budget of NT$800,000,000, accommodates approximately 30,000 adult students each year. By comparison, the National Taiwan University, one of the larger universities in Chinese Taipei, has an annual budget of $NT3,500,000,000 for its 21,000 students (Ministry of Education,

> 1996). Though gross numbers of this sort beg some level of refinement, the differential costs remain substantial and manifest. (Huang, 1998)

The above analysis does not consider that other costs, such as curriculum development and library resources, can be shared across virtual collaborations of institutions thereby lowering the costs to individual institutions. For example, the Pennsylvania Online World of Electronic Resources (Library POWER) initiative, will make thousands of periodicals and documents accessible over the Internet to state residents, realizing an enormous savings for individual libraries within the state: "If each library were to purchase these subscriptions individually it would cost over US$12 million. We're able to do it for the whole library system for just $1.25 million." (Wired News Report, 1998)

Costs to Society

And finally, when discussing cost-effectiveness, one must consider the societal costs to developing countries of not preparing their citizens to participate in an information-based global society.

The World Development Report 1998/99 (World Bank, 1998) warns that the global explosion of knowledge may either lift hundreds of millions of the world's poor out of poverty or it may create a widening knowledge gap, in which poor countries lag further and further behind:

> If knowledge gaps widen, the world will be split further, not just by disparities in capital and other resources, but by the disparity of knowledge. Increasingly, capital and other resources will flow to those countries with the stronger knowledge bases, reinforcing inequality. (p. 14)

The Report further recognizes that ICT can play a major role to play in reducing information inequities:

> This new technology greatly facilitates the acquisition and absorption of knowledge, offering developing countries unprecedented opportunities to enhance educational systems, improve policy formation and execution, and widen the range of opportunities for business and the poor. One of the greatest hardships endured by the poor, and by many others who live in the poorest countries, is their sense of isolation. The new communications technologies promise to reduce that sense of isolation, and to open access to knowledge in ways unimaginable not long ago. (p. 9)

And, as Potashnik and Adkins (1996) have pointed out, "even in countries which do not believe in the cost-effectiveness of information technology as a tool for mass education, it is important that they begin acquiring experience using this technology for educational purposes. Otherwise, educators in developing countries will be marginalized in the international dialogue on education" (p. 3).

In conclusion, assessing the effectiveness of ICT in education is a difficulty, multidimensional endeavor. When comparing ICT-mediated instruction with face-to-face instruction, it seems clear that ICT-mediated instruction is at least as effective. When considering what ICT-use enables educationally, it seems equally clear that ICT-enabled education has a distinct advantage over traditional methods in its ability to support new pedagogical methods, provide access to remote resources, enable collaboration, reach more people less expensively, and reach them throughout their lifespan. When considering whether ICT is "cost-effective" in educational settings, a definitive conclusion may not be possible for a variety of reasons. However, when considering the alternative of building more physical infrastructure, the cost savings to be realized from sharing resources, and the societal price of not providing access, ICT as a means of enabling teaching and learning appears to be an attractive and necessary alternative.

CREATING AN ICT-ENABLED LEARNING ENVIRONMENT

In this section, we will concentrate on the development of ICT-enabled learning environments, specifically on infrastructure, content, teacher education and training, and technical support.

Infrastructure

In order to make use of digital ICTs schools must be equipped with computers. In order to access the Internet from a computer, schools, homes, libraries, and other educational venues must be equipped with an Internet connection, either by means of the telephone or cable network and a modem or a direct connection. Many creative means to providing computers and building the necessary Internet infrastructure are being explored in countries throughout the world.

Education/Business Collaboration

Collaboration, including cost sharing, between education and industry to build ICT infrastructure is becoming commonplace. For example, the Bristol Education Online Network (BEON) project (http://www.education.bt.com/ednews/43beon.htm) and the follow-on Merseyside Education Online Network (MEON) (meon.eonic.net) are cooperative efforts of commercial companies British Telecom (BT) and International Computers Limited (ICL), local schools, and the University of Exeter School of Education. These projects seek to examine the impact of ICT on education. ICL is supply multimedia computers and BT the networking and access to remote services and the Internet to a number of schools in the area. As part of these projects, University teacher educators are linked with teachers via desktop videoconferencing to provide continuing professional development.

Business-to-Education Technology Transfer

One promising approach to equipping schools with computers inexpensively is to transfer the technology from government organizations and businesses to schools. In the U.S., the Government's *Computers for Learning* program (http://www.computers.fed.gov) donates surplus federal computer equipment to schools and non-profit educational organizations. Established by Executive Order, the program aims to provide hundreds of thousands of computers for teaching and learning.

Other non-governmental programs, such as the non-profit Detwiler Foundation's *Computers for Schools* (http://wwwnt.thegroup.net/detwiler) and the charitable organization *Computers for Children* (http://www.computersforchildren.com) in the United States and the industry-supported *Computers for Schools* program in Canada (http://www.schoolnet.ca/cfs-ope/welcome_e.html), are soliciting donations of “obsolete” or redundant computers from business, industry, and individuals, and refurbishing them before donating them to schools. As of the summer of 1998, the Detwiler Foundation has placed more than 40,000 computers in U.S. schools nation-wide. The goal of the Computers for Schools program in Canada is to place 250,000 computers in schools and public libraries by 2001. To date, the program has donated over 70,000 refurbished computers to Canadian schools and libraries.

School–University Partnerships

Although not primarily intended as infrastructure projects, partnerships between schools and universities often result in new infrastructure development. These projects typically target university/school connectivity for research, teacher education, and Internet access. As early as 1990, Wilbur and Lambert reported over 1,200 such partnerships in the United States alone.

Netdays

"Netday" initiatives, characterized as "high-tech barn-raising," are grass-roots efforts by community volunteers to wire classrooms, libraries, and computer labs so that they may connect to the Internet. Organizers of such efforts typically help schools to develop a technical plan that includes instructional goals, network and wiring architecture, network management and technical support, training, and an operating budget. On a specific day, volunteers from the local community do the physical labor necessary to run network wiring; greatly reducing the costs of providing Internet access within the schools.

Netdays began in 1995 as a local initiative in California, but have since become an annual national initiative endorsed by the President of the United States (http://www.netday.org), and have spread to countries throughout the world. For example, Netdays now take place Australia (http://www.netdayoz.edu.au), many European countries, (http://www.netdays.org/ en/projects/country.html), Israel (http://www.netdays.org.il), Japan (http://www.netday.or.jp/index-e.html), New Zealand (http://www.netday.net.nz), South Africa (http://www.netday.org.za), and, in Latin American and the Caribbean, UNESCO is sponsoring a netday initiative (http://www.unesco.org/events/latin/euro_america.html).

Community Networking

Although not strictly intended for educational purposes, many Community Networking initiatives have educational components and are worthy of mention. Community networks bring together entire villages, towns or cities into virtual communities to strengthening social ties, promote social participation, promote economic development, and build a sense of civic responsibility. Such initiatives establish affordable, community operated ICT systems that involve local individuals and organizations in learning about electronic communications, and help construct these systems to meet unique local needs.[3]

In an interesting example of how community networking can benefit educational institutions, the International Telecomputing Consortium (http://www.itc.org) is working with schools and universities in China to create school-based community networks. In these projects, participating schools (http://www.itc.org/chinaprojects.html) establish computer centers with Internet access for use by students and teachers in class. After hours, the center is open to parents and other members of the community who may not have Internet access. Teachers and students in these schools provide ICT training for members of the community. The school thus becomes the Internet access point for the entire community with some revenue going back to the school.

Technology Grants

Another useful method of providing support for ICT in education is the provision of specialized grants to individuals and educational institutions. Such grants programs serve a dual purpose of stimulating innovation in the educational community and targeting scarce resources on particularly promising applications.

Many for-profit and non-profit organizations offer such grants to teachers and schools. For example, the Hewlett-Packard (webcenter.hp.com/grants/index.html), Compaq (http://www.compaq.com/newsroom/pr/pr220698c.html), IBM (http://www.ibm.com/ibm/ibmgives), and Microsoft (academicoop.isu.edu) companies all offer equipment grants to educators. In the United States, the Department of *Education's Technology Innovation Challenge Grants* annually funds large-scale educational innovations with ICT (http://www.ed.gov/Technology/challenge).

Content

Beyond equipment and software, appropriate content is necessary to make use of ICT for educational purposes. In this section, we consider a few of the many initiatives related to educational content creation and standards.

Content Creation

Content is being created by many organizations including governmental agencies, commercial and non-profit organizations, mainstream and extremist political and religious groups, social clubs, universities, colleges, trade unions, public and private schools, libraries; collaborations between such groups; and individuals. Although some online content is specifically designed for educational purposes (cf. http://www.EDsOasis.org), most is not.

Indeed, the sheer amount of information available on the Internet, the ease with which it may be accessed, and the lack of standards for cataloging such information have created problems of information overload and quality control for parents, students, and educators worldwide. These problems, coupled with the preponderance of Internet-accessible content having been produced by a few developed countries – particularly the United States) – have led many to believe the Internet is a mixed blessing for education (see section below "Significant Issues" for more discussion).

The speed of the development of information overload may be illustrated by the fact that in June 1993 there were only 130 websites worldwide. By January 1997 this number had grown to a staggering 650,000. The number of websites has been more than doubling, sometimes trebling, every year since 1993 and is expected to do so for the foreseeable future. As each website usually contains multiple webpages, it is literally impossible for one person to view every webpage on the Internet. In another example, it is estimated that there were fewer than 100 Chinese webpages in 1994. Today, estimates place the number at over a quarter million offering everything from book reviews to travel guides, and the numbers continue to increase dramatically (Ramo, 1998).

Regional Collaboration

Countries with similar languages, cultures, or that have migrant populations may be able to economize in the creation of ICT-based content and tools by collaboration. For example, in Europe, the *TOPILOT* telematics project involved a management team and 15 school-based partners in the UK, the Netherlands, Belgium, and Germany in the development of a multimedia educational program for fairground, circus, and bargee families within the European Community, all living a traveling life-style. The project developed interactive CD-ROMs students could use while on the road as well as tools to be used for Internet-based interaction between tutors and students (Dobbeni, Marks, & Botke, 1998).

Schoolnets

One approach to facilitating access to appropriate educational content is the creation of a "Schoolnet." Schoolnets, also known as "national education grids," are regional, national or local projects that may include efforts to physically wire schools to information services, but that are fundamentally developed to provide access to appropriate educational content. Schoolnets may contain curriculum guides; collaborative online projects; email directories; links to other teachers, schools, and governmental organizations; online classes; tutorials; and news about conferences. For example, the United Kingdom's National Grid for Learning (NGfL) "is both an architecture (or structure) of educationally valuable content on the Internet, and a programme for developing the means to access that content in schools, libraries, colleges, universities, workplaces, homes and elsewhere" (ICT in Education News, 1998).

Schoolnet are being developed worldwide. European Schoolnet (http://www.eun.org/index.html), a project of the European Union, offers teachers access to a wealth of information about ICT use in education. Schoolnets now exist in Canada (http://www.schoolnet.ca/home/e/), France (http://www.educnet.education.fr/), Ireland (http://www.scoilnet.ie), Japan (http://www.schoolnet.or.jp/schoolnet/index-e.html), South Africa (http://www.gp.school.za /gsnsite.htm), Thailand (http://www.school.net.th), and other countries. The Canadian government has recently signed an agreement with the China State Education Commission and a Sino-Canadian joint business venture to establish a Sino-Canada SchoolNet that will develop online Chinese-Canadian educational programs and resources. This project will deliver services to students and teachers in both countries through a virtual campus (Zhu and Prescott, 1998).

Locally Produced Content

One of the advantages of new ICTs is that it empowers users to not only consume information, but also produce it. With a computer, printer, and desktop publishing software, any local educational group can produce high quality printed materials. With an Internet connection and website, any educational organization can "publish" content derived from local knowledge and experiences. For example, eighth grade students in the United States at Dakota Meadows Middle School in North Mankato, Minnesota, have written short, two-minute mysteries posting them on the World Wide Web and challenging other students to "Use your wits and detective skills to solve these cases." Over 20,000 people have visited the students' website (http://www.isd77.k12.mn.us/schools/dakota/mystery/contents.html). These same students have collected oral histories from members of the Mankato community about their experiences during World War II and made them available on the web (http://www.isd77.k12.mn.us/schools/dakota/war/worldwar.html).

In another example, the Summer Institute of Linguistics (SIL) has helped set-up Literacy and Awareness Publication (LAMP) centers in each of the 20 provinces of Papua New Guinea to promote literacy in approximately 850 local languages. Few, if any, literacy materials exist in the majority of these languages, and over 55 per cent of the population aged over 10 is functionally illiterate. At these centers, literacy texts are produced covering a wide variety of subjects including healthcare, hygiene and preservation of the environment that can be shared between the centers. The computers, scanners, digital duplicators might be new technology, but the materials produced on this equipment are in local languages based on local customs and culture for local audiences (UNESCO/UNICEF, 1997b).

Content Standards

Although many tools exist to help teachers and students locate information (cf. Alexia.lis.uiuc.edu/lrl/links/search.html), At present, a lack of commonly held technical standards inhibits sharing educational resources across institutions and between a wide range of technical environments. This presents a significant obstacle to realizing the educational potential of ICT.

At the moment, finding specific educational materials on the World Wide Web can be likened to a difficult and cumbersome scavenger hunt, often resulting in wasted time and unexpected results. For example, a teacher searching the Web using a popular search engine, Alta Vista (http://www.altavista.com), for educational materials on "Southeast Asia" would find over 77,000 related webpages including information about books, travel agencies, journals, music, colleges, personal travelogues, pictures, satellite images, maps, newspaper articles, and so forth. On the other hand, if the teacher had entered "Asia, Southeast", the search would return over 800,000 webpages!

Faced with such a hodgepodge of information, a teacher or student is hard-pressed to locate specific information or materials of use within the curriculum at a particular grade level. The results of such indiscriminate searches also raise the issue of the validity and reliability of the information. Once found, because of varying technical standards, materials created with one ICT-based learning system may not be usable in a different environment.

Several efforts to bring order to the chaos of the Internet and World Wide Web are underway. The European Commission has initiated a *Memorandum of Understanding: Multimedia Access to Education and Training in Europe* to this end. As of December 1998, over 160 educational organizations, government agencies, and commercial companies have signed the MoU. The MoU is intended to bring together:

> … key players to identify key common issues to the further deployment of ICT based learning services and the provision of multimedia access to education and training in Europe … there is a great need for widely accessible and re-usable digital content that would either be delivered over telecommunications networks, or stored locally. For such content to be useful, it would need to conform to certain standards, both pre- and post-development taking into account the multilingual, multicultural European learning environments, the diversity of curricula in the different European education and training programmes, and special needs such as those of the disabled and elderly. (European Commission, 1998)

By the creation of technical standards, projects like the Dublin Core Metadata Initiative (purl.oclc.org/dc) and the Instructional Management Systems (IMS) project (http://www.imsproject.org) may "help transform the end-user experience of the Web from the unstructured tangle it is today into something more like a digital library or virtual learning centre" (Sithers, 1998). If international agreement can be reached on an acceptable set of technical standards, educational materials developers will be able to embed in electronic materials information such as subject matter, grade level, educational objectives, and pedagogical approach. Teachers and students will then be able to search for educational materials with common descriptors and be assured that the materials, once found, will be compatible with local ICT applications.

Teacher Education and Training

To create ICT-enabled teaching and learning environments, it is also necessary to provide ICT training for teachers. As noted by Guskin (1996), "The changes being asked of faculty members in restructuring their work lives will be extraordinary and will require them to function in ways they never conceived of and for which they were not trained." In some countries, for example Great Britain, it is now required to have training in ICT-use to earn a teaching credential (Teacher Training Agency, 1998). Beyond preparative training, as educational applications of ICT continue to evolve, refresher training for experienced teachers will be necessary.

In one possible framework for organizing ICT training for teachers, McDougall and Squires (1997) identify five foci: (1) skills with particular applications, (2) integration into existing curricula, (3) IT related changes in curricula, (4) changes in teacher role, and (5) underpinning theories of education. The authors note that most ICT teacher training mistakenly focuses entirely on the first issue.

Furthermore, it may not be sufficient to simply provide training for teachers. For instance, Murphy and Gunter and others (cf. Sharp, 1998) advocate that ICT training be extended to educational administrators:

> Lack of teacher technology training has been the failure of most schools trying to grasp technology and harness the power that technology can bring to the classroom. However, successful technology training can be accomplished only through effective administrative leadership … These leaders must be knowledgeable in the use of technology and must show support by providing access to the equipment and materials necessary for successful integration. (Murphy and Gunter, 1997, p. 136; 138)

But, even more vital than ICT training for teachers and administrators, there is a continuing need to educate qualified teachers to staff schools. ICT is being used in a wide variety of ways to support teacher education as well and teacher training in ICT use. Email, websites, desktop videoconferencing, and other technologies and applications are all playing a role in such efforts.

Teacher Education

Preservice teacher education refers to the formal preparation of individuals to enter the classroom as qualified teachers. Inservice teacher education refers to on-going professional development programs offered to teachers once they have entered the profession. Perraton and Potashnik (1997), in a review of ICT use in teacher education, note that while most teachers working in schools worldwide have received some preparation, not all have received adequate preparation. In fact, many have received none at all. In India in 1996, for example, there were about 240,000 teachers who were not fully qualified. There also are severe teacher shortages in many countries, the problem being especially severe in South Asia and Africa (p. 4). Even in developed countries where there are sufficient numbers of teachers, as in the U.S.A., many are unqualified or underqualified to teach specialized subjects like mathematics and science (cf. National Science Foundation, 1998).

ICT is being used in a wide variety of ways to support both preservice and inservice teacher education. In Africa, UNESCO is developing a large distance education project to help eight countries train teachers and principals unreached by traditional training. The project, to be launched in 1999, is expected to train half of the teaching staff in five selected countries (UNESCO Education News, 1998). Also in Africa, education ministers from six Southern African Commonwealth countries have signed an accord to co-develop distance education programs with a priority given to the in-service training or teachers in science, mathematics, and technology (Commonwealth of Learning, 1998).

In Australia, the Faculty of Education at the University of Wollongong is linking teachers and postgraduate students directly to lecturers through email networks and provides online support to teachers in schools (Hedberg & Harper, 1996). *TeacherNet UK* (http://www.teachernetuk.org.uk), an independent organization, offers teachers the opportunity to develop an online profile of their interests, needs, and prior achievements, and then matches the individual participants accredited professional development programs. *TeacherNet UK* also enables peer support and mentoring through email and web-based discussion groups. In Iceland, the University College of Education offers a Bachelor of

Education (BEd) degree via the Icelandic Education Network (http://www.ismennt.is). In Denmark, teacher education is being conducted using ICT including computer-mediated conferencing (CMC) supplemented by satellite-based teleconferencing, multimedia and standard computer-based training (Ingesman, 1997). And, in a final example of how ICT is being used to support teacher education, the *TRENDS* (Training Educators through Networks and Distributed Systems) Project (http://www.lrf.gr/english/trends/trendshome.html), a collaborative effort of the seven European Union countries, is developing an in-service, school-based teachers training system based on multimedia and network technologies.

Teacher Training

As noted in a Finnish government report of a technology assessment project, "how computers are used in education depends on the pedagogical competence and technical skills of the teaching staff who must know how to exploit these modern technologies in pedagogically meaningful ways" (Finnish National Fund for Research and Development, 1998). Regional, national, and local plans for ICT in education typically include provisions for teacher training (cf. World Bank, 1998).

ICT training for teachers has at least two aspects – technical training and preparation to integrate ICT use into the curricula. First, teachers need technical training to learn how to use and maintain ICT equipment and software. Such technical training is being offered to teachers in a wide variety of ways. Preservice university-based courses, inservice workshops, commercial training programs, and other opportunities abound, many of which make use of ICT to deliver instruction (cf. "New Technology Training Method Brings Ga. Educators Out Of The Dark, 1997; McKenzie, 1998). Second, as "integration of technologies into curricula requires changes of huge magnitude" (Foa, Schwab, and Johnson, 1998, p. 1), training in how to integrate ICT-use into the curriculum is necessary. Such instruction should including effective teaching methods with ICT and the use of discipline specific applications:

> Most faculty members say they don't have the time or skills to experiment with the World Wide Web, let alone try complicated courseware, streaming video, or on-line message boards. They need sophisticated guidance, which most computer-help desks and student assistants can't provide. And they need more than a computing center's basic training in how to use Windows or word-processing software. (Guernsey, 1998, p. A35)

Many promising approaches are being developed to provide such support for faculty. In an expensive but effective approach, several universities have established "expert partners" programs. As reported by Guernsey, "people who fill the jobs have one thing in common: a hybrid expertise that blends academic computing with college teaching" (1998, p. A35). Staff who are both qualified academics within a discipline, and who have expertise using ICT for instruction, are hired "to provide faculty on-site, intradepartmental consulting and support in information and instructional technology for academic purposes to foster their awareness and use of technological resources, both within and without the University" (rits.stanford.edu/atss/atp/index.html).

Training methodologies vary, but "training of trainers" models are common and, in most instances, may be more cost-effective than on-site, small group or individual ICT training. In such programs, "teacher-leaders" are selected by a variety of criteria, usually including prior experience with ICT in education, staff development expertise, and commitment to the program by school and district administration. These individuals receive intensive training courses to master technical details and approaches to integrating ICT into the curricula. Once trained, they return to their educational institutions and provide ICT training and support for their peers. Such programs may also include on-going, long-term support for the trainers including site visits, computer-based conferences, and email mentoring. In large geographical areas, the responsibility for such training and on-going support may be delegated to regional ICT consortia, coordinated by a central administrative body. For example, the U.S. Department of Education has funded six Regional Technology in Education Consortia "to help states, local educational agencies, teachers, school library and media personnel, administrators, and other education entities successfully integrate technologies into kindergarten through 12th grade (K-12) classrooms, library media centers, and other educational settings, including adult literacy centers" (http://www.rtec.org).[4]

In an innovative and less inexpensive approach, students are being enlisted to provide ICT support and training for teachers. At Wake Forest University in the United States, incoming freshmen are hired and trained to work as Student Technology AdvisoRS (STARS). STARS are assigned faculty members to help implement ICT-based projects (http://www.wfu.edu/Computer-information/STARS/index1.html). Also in the U.S., a consortium of educational associations has launched a national grassroots project to train public school teachers to use computers and the Internet. The project, *21st Century Teachers* (http://www.21ct.org) hopes to recruit 100,000 educators this year to train their peers.

In the United Kingdom, the ICT Training Initiative of the Teacher Training Agency (TTA) (http://www.teach-tta.gov.uk) offers a combination of technical and discipline-specific applications training. The TTA, working with other educational organizations and a commercial company, will produce a package – including CD-ROM, video and paper-based materials – to help teachers identify their specific training and development needs in the use of ICT in teaching their subjects. Starting in April 1999, training – some of it Internet-based – will be offered to enable existing teachers to acquire the ICT knowledge, understanding, and skills which will be expected of all newly qualified teachers entering the profession from 1999.

In Australia, the *Connecting Teachers to the Future* project is providing teachers with training and a laptop computer, modem, and an Internet account "to empower teachers with personal skills in the use of information and communications technologies and to help them enhance the curriculum they develop for their students" (Gray & Buchanan, 1998).

Technical Support

Although standard service agreements, purchased separately or included in the purchase of ICT equipment and software, typically cover regular maintenance and repair costs, and may even include email or telephone support, such arrangements may fall short of what is necessary in educational settings. Without adequate technical support, schools have experienced "large workloads for existing staff, maintenance backlogs, and reduced computer use because computers were out of service" (U.S. Government Accounting Office, 1998). The provision of on-site, timely technical support may be critical to the success of an ICT-based educational program:

> There appears to be general agreement among observers that, at least in the foreseeable future, schools that are attempting to implement technology on a wide scale need to have on-site technical assistance. Although some sites have attempted to make do with help from a knowledgeable teacher volunteer or with part-time services from a district technology coordinator, such arrangements are often unsatisfactory. Like all of us, teachers trying to use technology in their classrooms want technical help on demand. Controlling a classroom full of students in the midst of some activity that requires technology when the system goes down requires flexibility and skill. If technical problems arise frequently and teachers have to wait hours, days, or weeks to get them resolved, they will abandon their efforts to incorporate technology. (Fulton, 1998b)

In universities, such support may take the form of technical staff assigned to a "computer center," "media center," or "distance learning center." In schools, knowledgeable peers, students, volunteers, specialized computer lab teachers are providing such support, and, less frequently, trained technical staff located either within the school or district office.

In an example of students' expertise being utilized, members of the American Technology Honor Society (ATHS) (nassp.org/aths/aths_frm.htm) provide ICT support and training for faculty members at their schools. In an example of how volunteers may provide such support, TECH CORP (http://www.ustc.org), a U.S.-based, non-profit organization, draws volunteers from the local communities who conduct teacher training seminars, serve as technology mentors to students and teachers, repair and install computers, participate in technology planning, and assist with the integration of technology into the curriculum.

SIGNIFICANT ISSUES

National Planning

ICT implementation in education is a difficult, expensive, and complex undertaking that must consider a host of issues including infrastructure, curricula changes, teacher training, technical support, and so on. Such an undertaking, especially on a national level, requires careful planning. Numerous developed and developing countries have implemented national strategies and plans for education that include ICT (cf. France [http://www.educnet.education.fr/pages/01/m01.htm]; Portugal [http://www.dapp.min-edu.pt/nonio/ ingles/docubase1i.htm]).

However, others have not: “Many governments stand at the threshold of the twenty-first century without clearly-defined plans and strategies about the use of educational technology – but they are making major new investments anyway” (World Bank, 1998, p. 31). A lack of careful planning may result in wasted resources or ineffective implementations. Drawing lessons from programs in Latin America, the Caribbean, and elsewhere about the effective incorporation of ICT in education, the Report identifies generic issues for planners to consider when developing national ICT in education strategies. These are broadly grouped into three categories: educational policy and goals-setting, teaching and learning, and institutional development and capacity building. In the Report, sound planning that sets priorities tied to existing and projected efforts for educational improvement is seen as critically important. The report also itemizes several successful strategies implemented to varying degrees by these countries including: (1) developing a national or regional plan for county-wide deployment of technologies, (2) implementing experimental projects to gain experience for country-wide deployment, (3) undertaking small-scale demonstration projects, (4) using technology to address educational equity issues (see section below on “Equity of Access”), (5) using broadcast technologies, including computer networks, to reach learners in remote areas, (6) investing in preparing students and teachers for technology-based jobs, and (7) creating schools using ICT as their core educational delivery system (p. 5).

Claeys, Lowych, and Van der Perre (1997), in an article based on interviews with a sample of 65 experts from across Europe about introducing ICT in education, summarize the respondents view of the role of government as developing a clear vision on reforming the educational system through ICT, enacting adequate funding measures, and establishing partnerships with education and industry for the development of educational software. In addition:

> … interviewees expect: (1) the development of a special cell in the department of education to support the introduction of ICT in education, (2) the development of incentives/projects, (3) the development of an advisory council to help the government promoting the introduction of ICT in education and, (2) the re-creation of the curriculum, in which information technology is embedded and an equivalent adaptation of the rules for examination. (p. 151)

Osin (1998), summarizing the experiences of projects meant to introduce computers into the educational systems of developing countries, offers prudent advice. He warns against beginning a project by purchasing computers, which often results in “a waste of money that could be put to better use” (p. 9). Instead, he advocates an eight step planning process beginning with gathering together the necessary expertise in an Advisory Committee that will define and implement a plan beginning with the careful execution of pilot projects. Osin also recommends training a cadre of instructors for teacher training, introducing computers into teachers colleges, and conducting both formative and summative evaluations of the pilot projects before attempting a large-scale ICT implementation.

Beyond planning, national governments have a role to play helping remove political and economic roadblocks that prevent sharing educational resources between countries. McIsacc & Blocher, (1998), in a discussion of distance education, advocate: “Courses offered globally should encourage broad international participation and have sliding scale tuition policies. Sharing in developing educational materials and courses saves the duplication of time and effort and conserves valuable national resources" (p. 46). Potashnik and Capper (1998), note:

> Employers and universities are now drawing both staff members and students from all corners of the globe. Consequently, they face new challenges in evaluating course work done at, and degrees earned from, unknown institutions in other countries. While accreditation has typically been controlled by individual countries, the globalization of distance education has created a whole new challenge in accreditation and certification of learning. (p. 45)

Potashnik and Capper point to the Global Alliance for Transnational Education (GATE) (http://www.edugate.org), an international alliance of higher education, government, and business, as one effort "to carry out the formidable task of creating a global certification and review process for education delivered across borders" (p. 45).

Government intervention may also help assure affordable ICT access for education. For example, telecommunications rates may be regulated to assure economical ICT access to educational institutions. In late 1996, the U.S. Congress enacted the *Telecommunications Act of 1996* (http://www.technologylaw.com/techlaw/act_index.html). The universal service section of the law, Section 254, will help U.S. schools and libraries obtain access to telecommunications services and technologies at discounted rates. And tax incentives, such as the *21st Century Classrooms Act for Private Technology Investment* (P.L. 105-34, Title II B, Sec. 224) (hillsource.house.gov/IssueFocus/SpecialProjects/ALearner/ALMain/tech.pdf), enacted by the U.S. Congress in 1997, are a potent means to encourage corporate ICT equipment donations to educational institutions. The Act allows companies to deduct the full price of a computer donated to a school within two years of purchase.

However, because ICTs are rapidly evolving, national educational policies on ICT, once put in place, "have to be regularly updated if they are to respond adequately to the challenge of effectively exploiting these constant changes to the technologies and their applications" (Byron & Gagliardi, 1996).

Intellectual Property

Intellectual property refers to original or novel creations of the human mind. Intellectual property rights give the creator exclusive right to use such creations for a specified period of time. These creations may include literary works, industrial designs, musical compositions and arrangements, paintings, trade secrets, sculptures, computer programs, performances, inventions, and so forth. Copyright, trademarks, and patents are legal methods to protect such rights.

The creation, maintenance, protection and transfer of intellectual property assets are increasingly important in today's global economy. The availability of ICT and the ease with which the fruits of human creativity may be duplicated, incorporated into multimedia products, and transmitted worldwide has led to increasing efforts to govern such use. In an era when every student and teacher is a potential publisher of multimedia materials that incorporate the works of others, information and training about the ethical use of intellectual property should be an important component of efforts to bring ICT use into the classroom.

Without international laws protecting intellectual property, and mechanisms by which to "meter" charges for its use, efforts to share resources globally will be inhibited. For example, the University of Pittsburgh in the USA, in cooperation with six major Chinese research libraries, has established the *Gateway Service Center of Chinese Academic Journal Publications*. The web-based system enables researchers to request articles from more than 10,000 Chinese academic journals housed in libraries throughout China, Hong Kong, and Taiwan while scholars from those countries have direct access to articles from most American journals. However, once requested electronically, the articles must still be printed and mailed because of publishers fears that copies will be distributed illegally over the Internet (Guernsey, 1998).

In universities, copyright concerns may be inhibiting the creation and use of ICT-based instructional materials. For example, increasing use of ICT has led to a re-examination of the question of ownership of materials produced by faculty:

> The ownership of intellectual property is among the most widely debated issues on university campuses today, and those debates go far beyond the distance learning issue itself. Typically, in settings other than universities, it is well settled that the material created by employees within the scope of their employment is owned by the employer. However, the unique mission of the university, academic tradition, and the essential principles of academic freedom have led faculty to claim that they own the material they create. Historically, many university administrations have asserted institutional ownership, but then allowed, or not challenged, the faculty position with regard to copyrights, at least in part because both the financial "cost" and the value of most copyrightable creations were usually insignificant when compared with the cost and value of patentable inventions. But as the potential value of copyrighted material escalates, particularly with the advent of multimedia software, and as financial resources diminish, many universities are revisiting who owns the intellectual property created by faculty. (American Association of University Professors, 1997)

International efforts are underway to develop global standards and agreements that will protect intellectual property rights while developing methods to allow access to, and sharing of, intellectual property. For example, The United Nations' World Intellectual Property Organization (WIPO), an intergovernmental organization with 171 participating countries (http://www.wipo.org):

> … is promoting the protection of intellectual property by the development and application of international norms and standards. The Organization currently administers 11 treaties establishing such norms and standards - 5 dealing with industrial property and 6 dealing with copyright, that set out internationally agreed rights and common standards for their protection, that the States which sign them agree to apply within their own territories. (http://www.wipo.org/eng/infbroch/infbro98.htm)

ICT itself is being used to provide assistance and information to educators and others interested in intellectual property laws. WIPO has just begun work on a global information network using the Internet that will facilitate the storage and rapid exchange of intellectual property information between all interested parties in governments and the private sector in member States. LexMunid (http://www.hg.org/guides.html), a global association of 152 independent law firms, offers a website directory with links to hundreds of legal guides about countries around the world, most of which contain information concerning intellectual property laws. Other organizations, such as the U.S. Franklin Pierce Law Center (http://www.fplc.edu), *Ruslaw* in Russia (http://www.ruslaw.ru/ intprop1.htm), and the Australian Copyright Council (http://www.copyright.org.au), offer websites with information about national laws governing intellectual property rights.

Equity of Access

Equity of access, put simply, means that all people, whether rich or poor, living in a developed or developing country, male or female, have access to the benefits of ICT-use. While this ideal is widely supported, it is a long way from realized.

Haves and Have-Nots

Access to and use of ICT is still predominately a phenomenon in developed, wealthier countries. This disparity leads to concerns that ICT will broaden and deepen the economic, educational, social, and political gaps that divide the developing from the developed nations, and the poor from the rich:

> … while all countries in the world have been affected to a greater or lesser extent be the influence of ICTs in various domains of daily life, it has been and continues to be a very uneven "revolution" with its catalytic effects on development in the rich industrialized countries of the North, serving to widen the disparities existing between them and the South … Within such a context, there is a real risk that technology will become just another means for widening the gap between economic "haves" and "have-nots", that it will develop into another way of imposing outside models on others, and that global culture, with its tantalizing images of potential wealth and symbolism will override and devalue local knowledge systems … As with most other areas of development, there is a huge gap between the North and the South in the exploitation of these technologies in education. (Byron and Gagliardi, 1996)

The World Development Report 1998/99 (World Bank, 1998), notes, "Poor countries – and poor people – differ from rich ones not only because they have less capital, but because they have less knowledge" (p. 1). This inequity has been recognized by international agencies such as the United Nations and World Bank, and governments of the developed countries. As was noted earlier, UNESCO, through the *Learning Without Frontiers* (LWF) project and other programs, is helping organize and finance pilot ICT in education projects in developing countries. National governments in developed countries, too, are taking measures to assist in the creation of ICT infrastructure in developing countries. For example, the Clinton administration in the United States is pushing for funding to help developing countries link to the Internet for commercial and educational purposes (Miller, 1998). But huge inequities exist that will be difficult to overcome.

If inequities in access to ICTs in developing countries can be overcome, it may enable their citizens to leapfrog over economic and educational barriers:

> … developing countries need not reinvent the wheel – or the computer, or treatment for malaria. Rather than re-create existing knowledge, poor countries have the option of acquiring and adapting much knowledge already available in the richer countries. With communications costs plummeting, transferring knowledge is cheaper than ever. … Expanding telecommunications holds the promise to improve every developing country's capacity to absorb knowledge, for example by providing opportunities high-quality, low-cost adult learning. (World Bank, 1998, p. 2; 10)

Expanding telecommunications capability also provides an avenue to reach distant markets with locally produced products while at the same time educating others about local cultures. The Catdang Village Project in Vietnam is using ICT to reach a worldwide audience with information about local cultures while exploiting economic opportunities. The web-based project, selling locally produced lacquered bamboo baskets, is aimed at "providing sustainable regenerative income for village artisans and their families" (http://www.itc.org/catdang_kr.htm). While economically oriented, the website contains cultural information and images of Catdang; a small village located over a hundred miles south of Hanoi.

Other inequities in ICT access exist. The poor are less likely to have access to ICT, in or out of school. As Byron & Gagliardi, (1996) found, "Even in the developed world, access to the benefits of these technologies has by no means been equally available throughout all sectors of the population, with certain sections of society remaining deprived of many of the advantages offered by ICTs" (p.2). And as a Benton Foundation report (1998) notes, instead of offering new economic opportunities to the poor, ICT may actually worsen their plight:

> … even as digital technologies are bringing an exciting array of new opportunities to many Americans, they actually are aggravating the poverty and isolation that plague some rural areas and inner cities. Advances in telecommunications are speeding the exodus of good jobs from urban areas to the suburbs, leaving inner cities and rural areas more isolated than ever from the kinds of jobs, educational opportunities, quality health-care services, and technological tools that they need to be able to contribute to the overall economy. This technology gap has ominous implications not just for the low-income communities that are directly affected, but for the entire society. (p. iv)

This same report found that schools in high-income areas were much more likely to have lower pupil–computer ratios and Internet access, a finding confirmed by Heaviside, Riggins, and Farris (1997). Throughout the developing world, the situation is much worse. Access to even basic communications technologies is limited to a few. In South Asia and Sub-Saharan Africa, there are about 1.5 telephone lines per 100 people compared to 64 per hundred in the United States (World Bank, 1998, p. 9).

In conclusion, when considering ICT, "threat and opportunity are opposite sides of the same coin" (World Bank, 1998, p. 14). ICT has the potential to greatly enhance the information-base, knowledge, and educational opportunities of the poor and of developing countries. However, such benefits will depend upon whether there is equitable access to ICT. If not, ICT may increase the gap between the haves and have-nots of the world.

Gender

According to UNICEF, over 130 million children of school age in the developing world are growing up without access to basic education, of whom nearly two of every three are female (UNICEF, 1998, p. 7). If lucky or privileged enough to attend school, a number of studies have shown females are far less likely to enroll in science, mathematics, computer science and engineering courses (cf. ethics.cwru.edu/ecsel/abstracts/ women.html; http://www.becta.org.uk/info-sheets/gender.html; http://www.nsf.gov/sbe/srs/ seind96/ ch1_cont.htm).

In the United States, Birdsell, Muzzio, Krane, and Cottreau (1998) report increasing use of the World Wide Web by women:

> In the winter 1997-98 surveys, 44% of the Web users were women, up from 21% in September 1995. As a portion of the overall US population, 3% of adult women in the September1995 survey said they logged onto the Web compared to 12% of men. Research now shows that 26% of all American women use the Web, as do 35% of men. (p. 1)

However, U.S. women, too, choose ICT-related careers less frequently, and are more likely to change career fields: "Women are leaving or avoiding computer careers in droves, citing discrimination by male co-workers, few role models, family-unfriendly work environments and a general sense that the field is irrelevant to their interests … The most immediate effect is to worsen the nation's shortage of high-tech workers" (Piller, 1998). In *America's New Deficit: The Shortage of Information Technology Works*, the U.S. Department of Commerce's Office of Technology Policy reported:

> Women--who comprise 51 percent of the population and earn more than half of all bachelor-level degrees awarded--earn about one-quarter of the bachelor-level computer and information sciences degrees awarded by U. S. academic institutions. More disturbing is the trend line: the share of all computer science degrees awarded to women in the United States has fallen steadily from a peak of 35.8 percent in 1984, to only 27.5 percent in 1994--the lowest level since 1979. (1997, p. 24)

As ICT becomes more commonplace in educational settings, gender differences in access and use of such tools and resources in schools are also emerging. Based on research synthesizing over 1,000 studies, the American Association of University Women (AAUW) Educational Foundation recently reported, "Girls have narrowed some significant gender gaps, but technology is now the new 'boys' club' in our nation's public schools. While boys program and problem solve with computers, girls use computers for word processing, the 1990s version of typing" (AAUW Education Foundation, 1998).

One means being explored of overcoming gender-based inequity in the study and use of ICT is to develop classes specially designed for female students (cf. Zehr, 1998). Another is the use of ICT to support mentoring. For the past two years, for example, Dartmouth College has offered *E-Mentoring* (http://www.dartmouth.edu/~wisp/ electronic_mentoring.html), a program that links female students with professionals in science, engineering, and mathematics by email to encourage them to enter and stay in traditional male professions. This effort has led to the establishment of MentorNet (http://www.mentornet.net), a national program that plans to provide mentors for 5,000 female students in traditional male disciplines over the next five years (Haworth, 1998).

ICT is also being used both to provide information about gender issues to teachers (cf. http://www.wri-edu.org/equity/gender.html), and to encourage women's use of information and communications technologies. For example, the *Women'sNet* (womensnet.org.za) project in South Africa offers a variety of information on women's issues and is planning to offer an Internet training program for women in the near future. *The Ada Project* (TAP) and its *TAP Junior* offshoot at Yale University in the United States (http://www.cs.yale.edu/HTML/YALE/CS/HyPlans/tap/tap.html), serves as a clearinghouse for information and resources relating to women in computing. The Center for Women and Information Technology at the University of Maryland Baltimore County (UMBC) (http://www.umbc.edu/cwit) is dedicated to addressing the technology gender gap. Its website includes curricular resources, news articles on gender and technology, and links to sites focusing on women, girls, and information technology.

Cultural Imperialism

Concerns about cultural imperialism and the impact of ICT on local cultures and languages – given the dominance of the Internet by the developed, English-speaking countries – are growing:

> … the Internet is supposed to be an open ground on which expressions and even representations of different cultures can be acted out in diversity. However, this promised diversity on the global network is set back and held in suspicion, for many, by the cultural imperialism represented by the West in general and U.S. culture in particular. Rather than empowering local and the marginal cultures to speak out for themselves, globalization appears to be synonymous with standardization and normalization of one privileged, globalized local culture over others. (Lee, 1998)

Such concerns are especially acute as they relate to the education of young people:

> One of the major concerns voiced [at the 1996 UNESCO Second International Congress on Education and Informatics in Moscow] was that unless minority groups and non-English-speaking countries consciously start providing information on the Internet, the western world and the English language will continue to dominate the system. The UNESCO Congress made it clear that, while the Internet enables countries of the North to share educational materials and research with the Third World and permits developing countries to make their own materials available online, it also reinforces a likelihood of "cultural imperialism." (Khvilon & Patru, 1997)

Language is frequently the focus of such fears. According to some estimates, 90% of all information posted on the Internet is in English (Herschlag, 1996). Surprisingly, however, there is near parity of the number of Internet users who are native English speakers (91 million) and non-native English speakers (71.3 million). But this may soon change. The fastest growing group, in terms of language, are those who access the Internet in languages other than English. When ranked by native language groups, the largest groups on the Internet are the Spanish-speaking (14.2 million), the German-speaking (13.7 million), and native Japanese-speakers (12.3 million). French-speaking Internet users, the fifth largest group, account for six million while Mandarin (Chinese) speakers account for 4.1 million. (Euro-Marketing Associates, 1998).

Whether the changing language demographics on the Internet will result in English becoming a common language for ICT-enabled discourse, or will result in a "tower of ICT-enabled babble" is an open question. Language translation software may offer some solutions to this problem (cf. http://www.unl.ias.unu.edu/eng/unlhp-e.html), but such technologies are far from mature. However, as Everhart (1998) noted: "we should not lose sight of the potential of these applications for enhancing global understanding. … Dance, music, collected memories, and shared imaginings can provide a common global language."

Paradoxically, despite fears of cultural imperialism on the Internet, use of ICT is also seen as a means to protect and project cultural, religious, and other differences:

> There is an important counter-effect or internal contradiction in our global, Net-based information society: simultaneously with the rise of global networked society there is an increase in national, ethnic, and religious identity politics and the resistances to globalization inherent in these movements. Many of the identity groups represent themselves as explicit points of resistance to a global system of any kind while simultaneously using the tools of globalization (Net communications, Web presence, satellite communications). (Irvine, 1998)

ICT is also enhancing the ability of people from different cultures to interact with and create cultural materials. For example, the Cassandra Project (http://www.nyu.edu/pages/ngc/ipg/cassandra) stages events on the Internet with performers from around the globe that incorporate dance, poetry, music, video, and drama using videoconferencing and audio streaming. Audiences worldwide are able to watch and participate. The Academia Sinica in Taiwan has developed a full-text searchable database (http://www.ihp.sinica.edu.tw/database/ index.htm) of Chinese classics, including the 25 Books of History and other philosophical and literary texts, making these cultural products available to a worldwide audience.

Whether the Internet will create a "Global Village" in which all participants' cultures and languages are equally valued, or foster an "invasion" by which diverse cultures and languages will be electronically subjugated, is an open question.

Pornography, Violence, and Censorship

Although connectivity, including access to remote resources, is a major beneficial feature distinguishing newer ICTs from old, such access has negative aspects. Whether – and to what extent – the free exchange of information will take place using ICT is being widely debated, with the transborder nature of ICT adding new, complex dimensions to such discussions (UNESCO, 1997, Part 3). Concerns about pornography, violence, and crime on the Internet are widespread (cf. http://www2.echo.lu/legal/en/internet/communic.html), and Internet political activism is also raising alarm in some countries (cf. http://www.savetibet.org). Anti-censorship (cf. http://www.eff.org) and pro-censorship (cf. http://www.enough.org) organizations are carrying the debate to a worldwide audience through ICT.

Human Rights Watch (http://www.hrw.org), a non-profit group founded " to end a broad range of abuses including … restrictions on the freedom of expression," recently reported that in many countries such concerns have given rise to efforts to impose censorship and restrict the free exchange of information on the Internet:

> … in a half-dozen countries, Internet access providers (including public libraries) were implementing filtering technologies and other voluntary measures to make prior censorship of on-line communications a reality. The trend is towards extending these technologies more broadly, with global implications for free expression. On-line content providers may soon be forced to start rating their content; those failing to rate their content may find their material blocked from public access. As local rating criteria are used to define ratings, the danger is that these restrictive criteria will limit the diversity of expression on the Internet, where content is as diverse as human thought. (http://www.hrw.org/hrw/worldreport99/ special/internet.html)

This debate is particularly serious when framed in the context of education. Given the ease with which students may access inappropriate materials using ICTs, critical questions about ICT-use in schools are being raised by religious organizations, government officials, administrators, teachers, and parents. A government official in Hong Kong recently warned, "While the Internet is a powerful source of information, it can also pollute young minds, so teachers should give guidance on the moral hazards in today's computer age" (Moy, 1998). In Argentina, religious organizations called into question school access to the Internet when material promoting the use of condoms was put on the Web by an AIDS foundation (Kolesnicov & Kolesnicov, 1998).

ICT manufacturers are introducing ways of overcoming the problem of school children being able to access content deemed inappropriate by local schools and parents. Such tools include "proxy servers" and "filtering" software. A proxy server is a computer on the school network on which educators can store pre-screened and approved information. Use of a proxy server limits student access to only those resources placed on the local server. "Filtering" software scans incoming information for specific words, phrases, or websites and blocks access to banned content (cf. http://www.schoolnet.co.uk/about/__ninaa.html; http://www.csm-usa.com/pr/981112.htm).

Beyond the questions raised by pornographic, violent, politically unsuitable, or criminal information on the Internet, another issue facing educators is the validity of the information available on the Internet. "While a wide realm of information is available on the Internet, it must be remembered that there is no monitoring agency and no restriction on posting false information for all to see" (Peace, 1998, p. 394). Students searching the Internet for information about the question of life in outer space are just as likely to find arguments based on religious believes (cf. http://www.creationscience.com/onlinebook/faq/ lgm.html), paranormal cults (cf. http://www.discribe.ca/ufo/contents.htm), as on scientific evidence (cf. ccf.arc.nasa.gov/dx/basket/pressrelease/97_75AR.html). It appears unlikely that this situation can be resolved. As Peace recommends, "Care must be taken by the instructor that students are made well aware of this situation, and that policies are developed to deal with the inevitable dilemma raised by a student citing incorrect information, found legitimately on the Internet, in support of a flawed argument" (p. 394).

CONCLUSION

As we trust has been demonstrated in this chapter, the use of newer, digital ICTs – because of the ability to integrate multiple media, interactivity, flexibility of use, and connectivity – are inspiring remarkable transformations in education around the world. These transformations hold promise for the improvement of the lives of the rich and of the poor, whether living in developed and developing countries. We have chosen to focus on existing, widespread uses of ICTs in education, but advances in wireless telecommunications, virtual reality, pervasive computing, artificial intelligence, speech recognition, and "next generation" networking technologies promise to remodel today's educational applications as comprehensively as the computer revolutionized yesterday's.

If we can claim to have detected any "theme" in our overview of ICT in education worldwide, it is this – ICT is neutral, human choices will determine how ICT will be used and whether the revolution in information and communications technologies will benefit all humanity. This is true at the micro-level, in the choices teachers make when deciding whether and how to use ICT in the classroom, to the macro-level, by the choices international, regional, and national governmental and non-governmental organizations (NGOs) make to support, or not, ICT access in formal and informal educational settings.

Of course, we hope the information contained within this chapter (which will no doubt be out-of-date shortly after publication) can help individual decision-makers reach informed choices about ICT in education. But more than that, we hope the remarkable developments reported in this chapter have touched the imagination and helped inspire a sense of urgency to act to so that all children may benefit.

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