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# ICT FOR EDUCATION: POTENTIAL AND POTENCY

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## INTRODUCTION

Social, economic, and technological changes of the past decades are making education and training for all more crucial than ever. Yet, educational systems, to different degrees worldwide, are struggling to afford educational opportunities for all, to provide their graduates with the necessary knowledge and skills for evolving marketplaces and sophisticated living environments, and to prepare citizens for lifelong learning. To meet these challenges, countries have to focus concurrently on expanding access, improving internal efficiency, promoting the quality of teaching and learning, and improving system management.

A linear expansion of existing processes and methods may not be sufficient to meet these objectives within a reasonable time. Some countries and institutions have turned to information and communication technologies (ICTs) and are exploring ways by which ICTs may help them in pursuing their educational goals. *This chapter reviews research and experience* resulting from these attempts, with a focus on the potential of these technologies to enhance access, efficiency, quality, and management.

Frequently, users and experts tend to concentrate on what a specific technology can and cannot do for education. But, as Table 3.1 illustrates, one technology may have different potentials depending on the purpose for using it. Also, many of the technologies have similar characteristics. Therefore assessments of the potential and appropriateness of particular technologies must be based on educational needs and objectives, rather than on the technologies themselves, as emphasized throughout this chapter.

## EXPANDING ACCESS

### Education for All: Unattainable Reality?

Expanding access to education is a matter of both economic development and social justice. It is true that worldwide illiteracy rates have declined in the past 30 years,[1] but it is also true that the demands on knowledge are much higher now than 30 years ago. In the past, an agrarian society could thrive economically even when more than half of its population was barely literate, but this is no longer possible in modern societies in the Information Age. To remain economically competitive and prosper in this global, knowledge-driven economy, countries cannot afford to have large sectors of their population excluded from education, or at the lower level of the educational process.

Education is positively related to development—that is, a higher proportion of the population of the most developed countries has attained higher educational levels than the population of developing countries. In regions that have stronger economies, such as North America, Western Europe, and parts of Asia, more than half of the college-age youth population is indeed attending college. Tertiary enrollment in the least developed countries is about 3%.[2] Approximately 90 million secondary-school-aged children in Southern Asia were not in school in 2000, and in sub-Saharan Africa, the number of school-aged children who are not in school continues to grow.[3]

**TABLE 3.1 • ICTS AND THEIR POTENTIAL FOR EDUCATION**

| TECHNOLOGY | OUTREACH | FLEXIBILITY* | SENSORIAL STIMULATION | INTERACTIVITY |
|---|---|---|---|---|
| Radio | High | Limited | Audio only | Limited |
| Television | High | Limited | Audiovisual | Limited |
| Video | Low | High | Audiovisual | Limited |
| PC | Low | High | Audiovisual | High |
| Internet | Highest | High | Audiovisual | Highest |

* Limited = students and teachers must be present during transmission. High = students can access the material at different times.

In many countries, whose budgets already are stretched thin, expanding access to education under traditional models is not an option. Dramatic conflicts and the burgeoning HIV/AIDS crisis (sometimes occurring simultaneously) in many countries have disrupted social services, including education, and diverted resources that could be used to maintain, let alone, expand educational opportunity. In Togo alone, public expenditure on education already represents 25% of total government expenditures. The country's illiteracy rate for youth aged 15-24 is close to 30% for both genders (45% for girls).[4] A program to eliminate illiteracy that relies on constructing more schools and hiring more teachers will require a level of public investment in Togo that may deplete the country's budget, leaving other essential services unattended.

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### Reaching Large Audiences

For more than a century, education has used technology to expand beyond the physical limits of schools and university campuses and reach more and nontraditional groups of students. For instance, in the beginning of the last century, Australia and New Zealand used a system of itinerant teachers to educate children and youth living in sparsely inhabited territories. The teachers maintained contact with their students through postal correspondence.[5] Radio, television, and computer-related technologies have expanded outreach potential further, and higher education institutions have been at the forefront of this expansion. In 1992, 41% of higher education students in Thailand and 38% in Turkey studied at a distance. The China TV University System (Republic of China) and Anadolu University in Turkey each serves more than 500,000 students per year. The United Kingdom Open University has provided education to more than 2 million individuals since it was established about 30 years ago.[6]

Distance learning institutions generally use a mix of technologies that may include printed material, videos, videoconferencing, CD-ROMs, e-mail, and the Internet. Many of them start with less expensive technologies, such as printed materials, and move to faster and more powerful resources as the need for expansion increases. The Open University of Hong Kong (see Box 3.1) is an example of this movement. (For more examples, see chapter 14.)

### Including the Excluded

Expanding access also means integrating populations that have been traditionally excluded from education for cultural and social reasons. In cultures with strict rules regarding interaction between genders, girls may be forced to leave school before puberty to avoid contact with male colleagues and teachers. For girls who remain in school, the rules regarding with whom they may or may not talk make it difficult to succeed. If a girl is having academic difficulties, she may rather fail than address the male teacher.[8] Technology can promote alternatives for educating women that are more cost-effective than all-female schools without disrupting cultural traditions. Television and radio broadcasts or Internet-based technologies enable girls to continue their studies from home or small learning centers. Technology functions as a neutral mediator, without gender or cultural allegiances, thereby facilitating communication. An essay exercise in a co-educational class at the African Nazarene University that required the use of computers illustrates the potential of ICTs to overcome barriers in communication. Faced with the challenge of learning a new technology, the students forgot tribal rivalries and gender differences to exchange information and work side by side.[9]

For persons with disabilities—who represent another significant and forgotten sector of the world population—technologies provide essential supports enabling them to participate in the educational system and the job market. VisualTek is a camera and monitor that enlarge print materials for people with visual disabilities. Voice synthesizers enable individuals with muscular dystrophies to communicate. Special computer software can be used to ameliorate learning disabilities or to enhance the memory of individuals with traumatic brain injury. Keyboard adaptations enable individuals with motor disabilities to write, and the Internet can connect homebound individuals to classrooms and workplaces.

Lifelong learning and economic development for populations living outside mainstream cultures are two other venues for using ICTs. The Gobi Women's Project provided nomad women of the Mongolian desert with literacy skills, training on livestock-rearing techniques, and business fundamentals to boost the local economy. The project—a three-way partnership among Danish International Development Assistance (DANIDA), UNESCO, and the Mongolian government—used weekly radio broadcasts complemented with printed material and scheduled teachers' visits. The pilot served 15,000 women in all 62 Gobi districts and initiated spin-off projects for the women's families. The Virtual Souk is a World Bank-supported project that helps craftsmen from the Middle East and North Africa to become economically competitive. The project trains the craftsmen in small-business administration techniques and use of the Internet, and supports their participation in fairs and regional conferences. A multilingual database catalogue offers the artisans' work to a worldwide customer base. The network receives and fills orders and is responsible for quality control. Currently, the Virtual Souk involves more than 700 artisans in Morocco, Tunisia, and Lebanon.[10]

Business organizations are investing heavily in distance learning technologies, particularly Internet-based applications, to train managers and employees while avoiding the costs and disruptions related to travel. The Ford Motor Company spent $100 million on a training network using interactive satellite technology that transmits up to eight live training sessions at a time to any of the 5,000 Ford dealerships across the United States. With the savings in training-related travel costs, the system paid for itself in three years. J.C. Penney, a large U.S. department store chain, uses a similar satellite network for its training program. Savings in travel costs are estimated at $1 million over a two-year period.[11]

## BOX 3.1 • THE OPEN UNIVERSITY OF HONG KONG

Hong Kong is a small but thriving economic community with one of the highest gross domestic products (GDPs) in Asia. During the 1980s, the demand for higher education in Hong Kong reached a critical point: the number of students graduating at the secondary level and desiring higher education exceeded, by far, the capacity of the few existing institutions. In addition, the expansion of high-tech industries required retraining for large sectors of the workforce. Limited physical space, funding, and qualified staff were barriers to the addition of new campuses. In 1987, the government provided start-up funds to open an independent institution dedicated solely to distance education at the tertiary level, the Open Learning Institute of Hong Kong (OLI). OLI became economically self-sufficient in 1994 and gained university status in 1997, when it was renamed Open University of Hong Kong (OUHK).

OUHK initially used for its courses prepackaged material, mostly imported from the Open University in the U.K. Printed materials, mailed to the student's home or workplace, are still used, but the courses are now developed by local experts and submitted to a system of internal and external reviewers. With foundation grants, the university developed a television broadcasting system and is implementing a Web-based project with four components: development of multimedia course materials; online drills and tests; monitoring and assessment of students' performance; and communications among academic staff, tutors, and students. In addition, OUHK is involved in research to develop language teaching and speech recognition software for the Chinese language, and in formulating quality standards for distance learning that will be adopted in Mainland China.

OUHK students can work independently or organize self-help groups in their homes, public libraries, the workplace, and the recently built campus. They must attend tutorial sessions in centers spread throughout Hong Kong and surrounding territories. A tutor supports a group of 30 to 35 students and meets with them every two or three weeks. Regular tutorial sessions are scheduled during weekdays and evenings, with optional sessions on Saturdays and Sundays. Beyond these sessions, tutors and individual students maintain phone contact as necessary. The tutors' main role is to support the students through courses and assignments. Some courses require compulsory day school and laboratory sessions. The students are expected to pay for the full cost of their courses, although the university offers public and private scholarships, grants, and loans. Employers pay the costs of employee training.

In 1992, OUHK had 18 degree-granting programs and graduated its first class of 161 students. In 1999, with more than 20,000 students, OUHK offered a doctoral degree program, about 10 master's, 41 bachelor's, and 27 sub-degrees or certificate programs through four schools (Arts and Social Sciences, Business and Administration, Education and Language, Science and Technology) and the Centre for Continuing and Community Education.[7]

## PROMOTING EFFICIENCY

### The Traditional Paradigm

The internal efficiency of an educational system is measured by its ability to deliver quality education in cost-effective ways. The traditional model for providing primary through tertiary education, adopted across the world, relies on three basic principles.

- Learners must congregate in a building where the teaching/learning process takes place.
- There must be a predetermined path, divided into grades, that leads to a diploma, and students must follow this path, regardless of their interests, needs, or abilities.
- There must be a hierarchic structure where the instructor is the provider of knowledge and the students are the recipients.

The traditional school is, therefore, a physical entity organized into classrooms where learners congregate according to a grade structure and constrained by the limits of space and time. If a school serves students from grades 1 through 12, it must have at least 12 classrooms to accommodate each grade separately. Each classroom must have one teacher. A certain number of teachers require a principal and, often, administrative and teaching support. If the number of students or grades increases, so must the number of needed classrooms, teachers, and support personnel. Generally, beginning in the seventh grade, another dimension is added to the classroom/grade framework: specialization. From then on, the number of teachers is related to both the number of classrooms and the number of specialties offered. Each school must have at least one mathematics teacher, a science teacher, a social studies teacher, and so on. As the educational level advances, classroom organizations will rely more on specialization than grades, but the framework is maintained.

To be cost-effective within this structure, the learning place must have a critical number of students that justifies school construction and maintenance, particularly personnel costs. In areas of low population density, building and maintaining schools to serve the traditional paradigm is economically prohibitive. The requirement of one specialist per specialty makes secondary schools an even more expensive venture. Some countries sidestep the problem by leaving the solution to individual families, with catastrophic results. If the families choose to move to urban areas and ensure their children's education, they jeopardize their country's fragile economic balance and further deplete the economy of their native regions. If they decide to remain, they jeopardize their children's future. Areas of high population density but weak economy are not free of problems. In this case, the traditional model encourages administrators to accommodate as many students as possible in one classroom to control personnel costs, which leads to overcrowded and unsafe environments that are unfit for learning.

### Learning Time vs. Classroom Time

The capacity of ICTs to reach students in any place and at any time has the potential to promote revolutionary changes in the traditional educational paradigm. First, it eliminates the premise that learning time equals classroom time. To avoid overcrowded classrooms, a school may adopt a dual-shift system without reducing its students' actual study time. Students may attend school for half a day and spend the other half involved in educational activities at home, in a library, at work, or in another unconventional setting. They may be required to watch an educational radio/television program and complete related activities, or work on a computer-assisted lesson at the school technology lab or in a community learning center. For areas with low population density, multigrade schools become viable alternatives. While more advanced students listen to an educational program on the radio or watch a television broadcast, the teacher can attend to the students who are in less advanced levels or vice versa.[12]

Latin America began experimenting with television to bring education to rural, low-population areas as early as the 1960s.[13] In 1964, the Mexican government tried television as an alternative to provide secondary education (grades 7-9) for children in rural communities. *Telesecundaria* was created to respond to the needs of rural areas where a general secondary school (grades 7-9) was not feasible, because there were not enough students and it was difficult to attract teachers. A quarter-century later, *Telesecundaria* (see chapter 10) has become a success story about the power of television to expand access and improve education in cost-effective ways.

### Student-Centered Curricula

Traditional educational systems also tend to rely on curricula that were developed at the beginning of the Industrial Revolution and are now disconnected from the realities of the job market. For bright students, these systems offer little in the way of motivation. Eventually, a few extraordinary students will be able to skip a grade, but rushing through the system is not encouraged, and early graduates may find obstacles when they attempt to gain access to the next level. For low-income students, who have less academic support, the schools offer even less: the wealthier schools lure the best teachers, leaving the least prepared for schools in poor and remote areas. When the need to work conflicts with schools' requirements, the student sees no reason to stay in school. As a result, these systems perpetuate social inequalities, lose many excellent students to boredom, increase the costs of education through high dropout rates and grade retention, and pass on to employers or other systems the costs of retraining their graduates.

ICTs have the potential to bring the products of the best teachers to classrooms anywhere in the world. For self-motivated, disciplined students, ICTs can speed the path toward a degree and expand their learning options through self-study. Students can "shop" courses on the Internet and choose their own program of study and schedules. Students in virtual schools (see Box 3.2) can take extra online courses to graduate earlier or fulfill specific interests and curiosity. For those who need to balance studies with work and family obligations—full- or part-time workers, parents of small children, homebound individuals—this flexibility may be most cost-effective for them.

The management of distance learning projects is not without difficulty, and, in many cases, local regulations function as obstacles to innovations (chapter 4 includes a discussion of this topic). However, the demand for more and specialized education is encouraging new arrangements that rely on ICTs to establish communication networks among partner institutions and facilitate student-centered, rather than program-centered organizations, such as the University of the Highlands and Islands (see Box 3.3).

## IMPROVING THE QUALITY OF LEARNING

### Learning about Learning

Research on brain physiology and cognitive psychology is challenging the traditional model of learning as mastery of facts and concepts. Descartes's proposal, "I think, therefore I am," is only partially true. Thoughts, feelings, dreams, and imagination are equally involved in the complex phenomenon that is human nature.[16] The acquisition of knowledge encompasses more than cognition. Perception, for instance, includes at least two basic components: (1) an "objective" component mediated through the senses, which provide the brain with information about the objects surrounding us, their descriptions and location, and our position in relation to them; and (2) a "subjective" component that analyzes the perceived objects through the lens of personal experiences and idiosyncrasies, previous knowledge, and cultural biases.[17] A person born and raised in New York City sees only snow, while an Eskimo sees a variety of landscapes and resources for survival.

Images are key components of the process of acquiring and using information because of their ability to condense large amounts of data. Research on working memory proposes that information is stored as images in visuospatial sketchpads to be used later. The process involves both imageries—the mental reconstructions of objects no longer present to our senses, and imagination—the mental construction of unknown objects. In addition to their role in retention and recall, images have the ability to decode unfamiliar symbols into known representations, a helpful function in language acquisition. Textbook images traditionally have been used in foreign language classes with this decoding function. Images are equally important in the acquisition of science and mathematics, which, similar to a foreign language, have their own symbols, terminologies, and grammatical structures.[18]

Although definitions of quality learning may disagree on details, it is generally accepted that, for learning to occur, the learners must be motivated, basic concepts must be understood, and knowledge must be advanced through more complex, higher-order thinking skill tasks. As we move away from linear learning, we get closer to how the brain functions. ICTs diversify the systems of representation through the use of various types of stimuli (images, sound, and movement) and address the needs of diverse types of learning (visual, psychomotor, and affective). In addition, ICTs have

## BOX 3.2 • THE VIRTUAL HIGH SCHOOL (VHS)

The Virtual Schools is a research-based project administered by a partnership between the Hudson Public School (Massachusetts, USA) and The Concord Consortium. The project explores the potential of ICT to improve the quality and accessibility of courses offered at high schools without expanding school enrollment. Through the Internet, participating schools can offer new courses and more courses without the need for increasing enrollment to justify the expenses. The project functions as a cooperative. Each participating school contributes at least one teacher and a site coordinator to the project, and, in exchange, the school can enroll a preestablished number of students in any VHS courses. A site coordinator helps to recruit the students and teachers, ensure that the technology is available and functioning, and provide support to the students. The advantage of the cooperative system is that the major cost of a project—personnel—is shared among all participants.

Before developing the online course, the teacher must complete a graduate-level course on design and development of network-based material. Each online course may take a year to develop, and must be approved by the school principal and VHS central staff. More recently, an Evaluation Board has been formed to define standards of quality for the courses. The courses, mostly one semester long, are taken for credits as core subject or elective. The courses are mostly interdisciplinary and use student-centered, hands-on instructional strategies that emphasize collaborative learning and inquiry. Students can take the course at home or during school time. In this case, the VHS coordinator functions as a tutor. The online courses are housed in a LearningSpace educational environment that enables teachers to deliver lectures, moderate student discussions, conduct assessments, and receive students' work. Students can submit work individually or in groups and can participate in discussions with their peers.

The first semester of the project was hampered by a series of technical problems and the lack of participants' experience with the process. For instance, because staff underestimated the server capacity that would be needed to support 350 students online, the courses were offline for a few weeks. As time passed, technical difficulties decreased, the teachers learned how to manage the logistics of online teaching, and students improved their understanding of the responsibility and persistence necessary to participate in distance learning. During the 1997-98 school year, the project had 30 participant schools and offered 30 courses to 700 students. In 1999-2000, the number of schools grew to 87, and the project offered 94 courses to more than 2,500 students. It is estimated that the project will serve more than 6,000 children over the five-year grant period.[14]

### BOX 3.3 • THE UNIVERSITY OF THE HIGHLANDS & ISLANDS (UHI)

Scotland's Highlands and Islands region faces many of the problems common to developing countries. The region is geographically dispersed, with a predominantly rural population. The weak economy is heavily dependent on small business and medium-sized enterprises, and the labor force includes unusually large numbers of self-employed, part-time workers and unemployed. Demographic dispersion, multiculturalism, and bilingualism challenge the planning and implementation of local educational systems.

In 1993, UHI was created to promote economic and social development in the region. Its first priority was to provide relevant education and training to the large number of local unemployed and underemployed. To respond to the diverse interest and needs of these nontraditional students, UHI changed its course structure from grades into thematically oriented modules. For each module completed, the students accumulate credits, and, upon completion of 120 credits, a certificate is issued. Paid and unpaid work may count toward credits. The students work at their own pace, and no time limit is imposed. Rather than expecting students to complete degrees, UHI sees them as lifelong learners.

This student-centered structure increases the demand for diversified curricula. In response, UHI has built a network of experts to develop and implement a variety of courses. Through technology, including videoconferencing and the Internet, UHI connects more than a dozen colleges and research institutions with a network of nonformal learning environments (businesses, public agencies, learning centers) where students work under the guidance of tutors. UHI students are never really remote; they maintain regular contact with tutors and professors through e-mail, telephone, and videoconferencing. This networking system ensures a critical mass of students that justifies the costs of producing and implementing a large number of courses. Currently, UHI serves more than 22,500 students, of whom 4,546 are in higher education programs.[15]

the potential to enhance educational quality by increasing motivation, facilitating acquisition of basic skills, promoting inquiry and exploration, and preparing individuals for the technology-driven world.

## Motivating to Learn

An effective teaching/learning process must stimulate intellectual curiosity and offer a sense of enjoyment that will move the students from the passive role of recipients of information to the active role of builders of knowledge.[19] Yet, engaging the learner in this process can be the most challenging task for teachers. ICTs are effective instructional aides to engage students in the learning process.

Videos, television, and computer multimedia software provide information that can be authentic and challenging in addition to stimulating students' sensorial apparatus through images, color, sound, and movement. A project in Malawi filmed community members in their traditional jobs to introduce scientific concepts to elementary school children.[20] Brazilian *Telecurso* (see chapter 10) is a televised educational program for young adults in search of a high school equivalency diploma. The program also uses videotapes of activities familiar to the students when introducing abstract concepts.[21] A training program for bank clerks in the United States was unable to offer on-the-job training because banks refused to accept trainees without some experience. The instructors decided to use videos of actual clerks working at a local bank and trainees role-playing clerk-customer situations. Trainees watched the movies and discussed the tasks involved, potential problems, preferred solutions, and their weaknesses/strengths. After the videos were introduced, the program placement rates increased from 70% to 93% over a two-year period.[22]

Although radio programs do not have the visual appeal of television or computer, Interactive Radio Instruction (IRI) uses songs, drama-like plots, and comic situations to attract and maintain the attention of students of all ages in rural and low-income areas of developing countries (see chapter 9).

## Facilitating the Acquisition of Basic Skills

Transmission of accumulated knowledge to new generations is an essential component of the educational process. This includes basic skills and information that are at the foundation of more complex knowledge. It would be inefficient to use a time-consuming process, such as inquiry and exploration, to transmit basic information. In addition, nonstructured learning environments based solely on inquiry and exploration may be confusing and overwhelming for some children and youth. These students will do better in well-structured classrooms, where the information is broken into less complex units, thus making it easier to understand. Exposition and practice strategies help to structure the classroom, enhance retention and recall, and cut learning time.

Educational television programs, such as *Sesame Street*, apply repetition and reinforcement to teach children about letters, numbers, or colors. Computers have three attributes that make them powerful aides for drill and practice strategies: large memory, speed, and the capacity to repeat the same task an infinite number of times without reducing performance. In addition, they provide students with the opportunity to learn on their own time and at their own pace. Computer-aided instruction (CAI) has been used successfully in different settings for basic skill instruction. CAI programs are divided into modules that maintain a hierarchy of concepts and skills. The students have to master each module before being allowed to move to the next, more complex level. An evaluation at the end of each module gives the students immediate feedback. If they respond correctly to a determined percentage of questions, they advance. Otherwise, they repeat the module or enter remedial units until the skills or concepts are mastered. The program can keep a history of the students' performance—lessons learned, topics with which the student had more difficulty, strategies that improved learning, and how many times the student had to repeat the module. With this information, the teacher can develop an individualized plan that addresses each student's specific weaknesses and strengths. CAI was introduced as an aid in mathematics classes, but it is now used for different disciplines, grade levels, and objectives. The military has used CAI in training for a long time. Overall, research shows that when CAI is applied well, users learn faster, retain more, and tend to have a more positive attitude toward learning than students receiving traditional instruction.[23]

Computers also can be used as auxiliary tools in mathematics and science classes to free teachers' and students' time. While computers work on repetitive tasks (such as long calculations and statistical computations), teachers and students can concentrate on analytical activities that require higher-order thinking skills.[24] Research indicates that elementary and secondary school students who use calculators have higher test scores and better attitudes toward mathematics than their peers who do not use calculators. Elementary school children who use computers and calculators in the classroom were found to understand mathematical concepts much earlier than expected.[25]

## Fostering Inquiry and Exploration

Although basic skills and information are essential components of the teaching/learning process, learning is more than information transfer. Learning requires the ability to analyze and synthesize information, use it in diverse circumstances, and propose new lines of inquiry that foster knowledge. Inquiry and exploration are essential strategies to attain those abilities. Astronomer Carl Sagan used to say that all children start out as scientists, full of curiosity and questions about the world, but schools eventually destroy their curiosity. ICTs have the potential to restore curiosity to education.

ICTs can take students on exciting journeys through time and space. Movies, videos, audio technology, and computer animations bring sound and movement to static textbook lessons and enliven children's reading classes. They also provide social studies and foreign language students with vicarious experiences of distant societies and bygone times. Spreadsheets can store and analyze large amounts of data necessary for complex math and science studies. Computer simulations transform risky and expensive experiments into safe and cost-effective procedures. The Internet offers virtual reality settings where students can manipulate parameters, contexts, and scenarios.

Computer simulations are a good example of the power of technology to improve the learning process. The flight simulator has been used for decades as the initial step in training airplane pilots. A flight simulator offers trainees the opportunity to practice the proper skills to control the plane and deal with emergency situations without risking lives or property loss. Although flight simulators can be complex and expensive machines, no pilot training program would question their utility. Simulators also are becoming essential tools in medical training. Through their use, medical students and residents are introduced to risky and invasive procedures without endangering patients' lives or exposing them to unnecessary pain and discomfort. Simulations are particularly helpful in situations that are too risky, expensive, or time-consuming to allow real-life experiments. For instance, welding simulators have proved to be a cost-effective method to train future welders. Without simulators, this training requires long hours of practice and burning expensive electrodes.[26] Simulations also enable students to test explosive materials virtually without running the risk of real explosions, and to "experiment" on animals without the ethical implications of real-life procedures.

For elementary and secondary school students—and sometimes even for adults—exploring the Internet can be a fun and enriching experience, or a frustrating adventure in trivia. Teachers and instructors play an important role as guides and facilitators by providing background material and guidelines for the search. They also need to monitor the process, particularly for younger students, who tend to browse the Web, rather than follow structured search plans. Teachers and instructors also are instrumental in helping students to separate unreliable sources from reliable ones and make sense of the large amount of information that may overwhelm them.[27]

### Preparing for the "Real World"

Globalization, creativity, and collaboration are key words in the modern workplace, where employers and employees are expected to share knowledge and work together toward common goals. In traditional classrooms, students work in isolation, doing tasks that emphasize conformism and boost competition. Trained in such environments, students may leave the school ill prepared to share ideas, divide tasks, or accept different points of view. Since ICTs can overcome physical and geographical barriers and facilitate communication, they have the potential to eliminate the artificial boundaries between schools and the outside world, and promote an environment that emphasizes collaboration rather than competition.

Videos and computer animations enable students to "witness" a volcano eruption to learn about pressure, rock formation, or psychological and sociological responses to crises. A simple radio or tape recorder can allow students in a foreign language class to listen to native speech regardless of their teachers' origin. Better yet, with interactive technologies, such as two-way radios or videoconferencing, students can communicate with native speakers without leaving their classrooms.[28] Videos, DVDs, computer software, and the Internet bring to schools anywhere in the world information that can be obtained only through the use of powerful scientific instruments that no single school can afford.[29]

More than any other technology, the Internet opens new opportunities for collaborative work. From group discussions to full collaborative research projects, the Internet has the potential to connect classrooms to research centers and students to actual scientists, as does the Global Learning and Observations to Benefit the Environment (GLOBE) (see Box 3.4). Research on the Apple Classrooms of Tomorrow (ACOT) indicates that technology-rich classrooms promote teamwork and encourage tolerance for alternative viewpoints, two essential skills for increasingly complex and diverse workplaces.[30]

## ENHANCING THE QUALITY OF TEACHING

### Teacher Training

Learning is only one component of the educational process, and quality learning cannot be attained without good teaching. Yet, teachers in general, and good teachers in particular, are in short supply even in developed countries. In the United States, for instance, the National Commission on Teaching and America's Future anticipates the need to hire an additional 2 million teachers in all teaching fields over the next decade to replace an increasingly aging workforce. For developing countries, in rural areas and in some specialties such as math and science, the teacher shortage has become critical.

Simply hiring a teacher does not ensure quality education. To be effective, teachers must keep abreast of new perspectives on learning theories and their area of specialization, a task that becomes impossible when teachers work in distant, isolated areas. The mentoring process that has been used traditionally to prepare new cadres is an extra burden on experienced teachers, particularly in places where they are already in short supply. Some schools of education are using videotaped sessions to prepare new teachers to enter the classroom without relying solely on mentors. The process frequently involves videotaping experienced teachers during regular classroom time. Student teachers observe their experienced peers in action, analyzing in detail the strategies used to present the material and interact with the students. The trainees then practice mock lessons with a group of peers or volunteer students while being videotaped. Peers and instructors review the tapes, highlighting weaknesses and strengths and making suggestions for improvement. Only after completing this process is the student teacher sent into actual classrooms.[32]

Videos can also be used to analyze teaching styles and idiosyncrasies and help educational systems to change their approaches. A research project related to the Third International Mathematics and Science Study (TIMSS) videotaped mathematics and science teachers in Japan, Germany, and the United States. The study analyzed variations in teaching style and lesson content among the three countries, looking for correlations between those dimensions and students' performance.[33]

ICTs can be used as tools for training and support of teachers, regardless of their geographical dispersion. Scripted lessons in conjunction with educational programs via radio and television, such as the IRI and *Telesecundaria* projects, ensure that all students receive quality, updated information, while imparting to inexperienced and generalist teachers the appropriate content knowledge and new pedagogical strategies. The use of technology for teacher training has at least three major advantages: it reduces travel costs, avoids disrupting classroom routines, and familiarizes the teachers with the technology. (For a fuller discussion of this theme see chapter 8 on teacher training and

## BOX 3.4 • GLOBAL LEARNING AND OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

GLOBE is an Internet-based project that allows students and teachers, in kindergarten through high school, to contribute to scientific research. GLOBE focuses mostly on mapping and understanding patterns and changes in three major areas: atmosphere/climate, hydrology/water chemistry, and land cover/biology. The project, launched on Earth Day 1994, is administered by a partnership that includes some of the most renowned scientific organizations in the United States, including the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).

The project has three main objectives: to improve mathematics and science education across the globe, to raise environmental awareness, and to contribute to a worldwide scientific database about Earth. To attain these objectives, GLOBE scientists help teachers and students develop projects such as measurements of pH in the water, analyses of temperature readings to observe changing patterns, etc. GLOBE can be implemented in different ways: as part of a science class, a separate class, a club, a lunch group, etc. In kindergarten and grades 1-3, GLOBE teachers work in a project with 10 or fewer students, but as the children advance, the groups can be much larger. The students conduct measurements and analyze data that are then stored in a central database, and scientists use these data for their research. Data and findings are available to all participants in numeric and graphic representation, and ongoing communication between schools and scientists is maintained. To ensure that the data collected are compatible, participant schools must use the same software and measurement tools and obey the project's scientific protocol. Approximately 9,500 schools in more than 90 countries participate in GLOBE, including schools in Benin, Burkina Faso, Cameroon, Chad, Gambia, Ghana, Kenya, Mali, Namibia, Senegal, South Africa, and Uganda.

An evaluation of GLOBE found that participating students perform better than their peers in activities that require an understanding of science, including the ability to interpret data and apply scientific concepts. They also showed a greater appreciation of science. In addition, the project instills in the students pride in their work, which is taken seriously by scientists and community members. For instance, GLOBE students in a North American school were asked by their local fire company to examine the reason for a foul smell in its station. The students' pH measurements of the local water supply helped government scientists to find a gas tank leak in the vicinity. The gas was infiltrating the soil and causing health problems. The students' participation was instrumental in solving the problem and was the best possible lesson in the importance of science for everyday life.[31]

development and chapter 15, which describes experiences in the use of technology for teacher training.)

### Teacher Support

The Internet has myriad Websites to help teachers develop or improve lesson plans, exchange ideas, obtain information, and find free animations and simulations to enliven their lessons. Most Internet-based collaborative learning projects include teacher support and training, and conference proceedings are published regularly on the Web. Chat rooms or forums may become a laboratory for new ideas. For instance, teachers in Soweto, South Africa, used their online connection with schools in Birmingham, U.K., to create a support network and promote discussions on curriculum reform and school management practices.[34] Indeed, contrary to the notion that technology is replacing the teacher, ICTs have expanded the quantity and quality of resources available to making teaching a less lonely endeavor.[35]

### Teacher Empowerment

More important still, research indicates that the introduction of ICTs for educational purposes has the potential to bring positive changes to teaching practices. In a survey of more than 2,000 teachers and school principals across the United States, the teachers stated that the technology helped them to become more effective (92% of respondents) and creative (88%). Both teachers and administrators agreed that technology had reinforced instruction, and functioned as a motivator for the students, who were more prone to ask questions and participate in the lessons.[36] More dynamic classrooms were also observed in evaluations of ACOT project.[37]

Despite this potential for training and support, ICTs have not been accepted easily among teachers. Some complain that scripted lessons take away their ability to address students' individual differences and improve their own teaching strategies. Others fear that technologies will reduce the role of teachers in defining curriculum and educational strategies, or totally replace them. This theme is discussed further in chapter 4.

## IMPROVING MANAGEMENT SYSTEMS

Education policy development is an intricate process that requires reliable, timely, user-friendly data. ICTs can be valuable for storing and analyzing data on education indicators; student assessments; educational, physical, and human infrastructure; and cost and finance. The use of computer-related technology is particularly helpful in this field. For instance, administrators and policy makers can construct virtual scenarios around different policy options to determine needs and analyze potential consequences. Each scenario can be analyzed and evaluated systematically, not only in terms of its educational desirability, but also in terms of financial affordability, feasibility, and sustainability over a sufficient period of time to show results.[38]

The same elements of computing and telecommunications equipment and service that have made businesses more efficient and cost-effective can be applied to schools and educational systems. ICTs can help administrators and school principals to streamline operations, monitor performance, and improve use of physical and human resources. More than other technologies, computer-related technologies have the potential to support the management of complex, standards-related instructional processes in relatively simple ways. They also can promote communication among schools, parents, central decision makers, and businesses, thus fostering accountability, public support, and connectivity with the marketplace. For instance, the Union City School District, located in one of the most impoverished communities in the United States, accepted an offer from the

### BOX 3.5 • ICTS FOR EDUCATION MANAGEMENT AND TEACHER TRAINING, A CARIBBEAN EXPERIENCE

The Joint Board of Teacher Education (JBTE) is a partnership among the University of West Indies, Mona Campus, three Ministries of Education, 14 training teacher colleges, and three teacher unions and associations in the Bahamas, Belize, and Jamaica. Its mission is to guarantee the quality of teacher education in the Western Commonwealth Caribbean. During the 1980s, the JBTE introduced significant reforms in the teacher education system, including alignment of teacher preparation programs with the countries' national curriculum; establishment of common admission criteria, curricula, and examinations in all teacher preparation programs; and adoption of a semester structure to deliver the programs with external semester examinations. An immediate consequence of the reform was a significant increase in the number of examinations developed and managed by the JBTE (from about 12 to more than 300 each year). However, as the demand for resources increased, the flow of money to the education sector had been reduced.

Personal computers were used initially at JBTE to produce the examinations. With time, the Secretariat expanded their use to process the exams. PROSOFT, a small Jamaican software firm, was contracted to build a record system that included data on staff and students (demographic information, courses taught/learned, etc.). The teacher preparatory colleges became interested. At their request, JBTE and PROSOFT developed the College Manager, a management system that handles student and staff matters at each college, and allows for online transactions between the colleges and the JBTE/Ministry of Education system. The project faced many difficulties, such as delays in implementation, software bugs, a fire that destroyed part of the database, shortage of competent staff to coordinate and manage the process, and high turnover of clerical and administrative staff.

Despite all of these difficulties, the JBTE partners were able to install a management information system customized to their needs. The losses associated with the delays in the project—which took seven years to complete—were compensated for by the increase in computer power associated with declining prices. The central database has sped up the process of producing the JBTE examination and processing results significantly. JBTE is now planning to expand the use of ICTs for online teaching and support of teachers and student teachers. Some of the technology's potential put in place was not planned originally, such as creation of a common pool of teacher college applicants. Before, the colleges received and processed applications independently. While one college had to refuse good students for lack of accommodations, another college might have to accept students who were less qualified. The common pool ensures that colleges have a more qualified group of students, and good students do not miss the opportunity to enter a teacher preparatory college.[40]

local telephone company to install computers in a pilot middle school and the homes of its teachers and parents. All those involved received training. The project improved communication significantly among parents, teachers, and school administrators and was expanded to include other schools.[39] An example of the use of computer-related technologies to address increasing demands in a time of reduced resources is provided by the Joint Board of Teacher Education (JBTE) in the Western Caribbean (see Box 3.5).

## HOW EFFECTIVE?

The preceding sections of this chapter outlined from research and experience the potential of ICTs to enhance educational policies, objectives, and practices. The effectiveness of ICTs—the realization of their potential—depends to a large extent on the context and quality of application. Moreover, since ICTs are only tools for education, it is difficult to isolate the factors that may be contributing to a positive result—such as educational philosophy, quality of teaching, parent support, and students' characteristics.

With these caveats in mind, evidence from large studies and meta-analyses suggests that use of ICTs, particularly computer technologies, is correlated to positive academic outcomes, including higher test scores, better attitudes toward schools, and better understanding of abstract concepts.[41] A longitudinal study of a statewide experiment with computers in the classroom found that those most in need of help—low-income, low-achieving students, and students with disabilities—made the most gains.[42] In addition to better performance in traditional measures of academic achievement, a secondary benefit of ICTs in education is to familiarize new generations with the technologies that have become integral components of the modern world. However, research on the effect of ICTs on academic achievement continues to be open to criticism (as with all other areas of education). Critics deny positive findings as the result of flawed studies, while supporters promote positive results without sufficiently evaluating the quality of the studies.

In the final analysis, ICTs are as good as how they are used. The path from potential to effectiveness is neither easy nor automated. Chapter 4 deals with conditions for and constraints of ICT effectiveness, and Part II elaborates on the options and choices to be made in applying ICTs in education.

## ENDNOTES

1 Across the world, from 1970 to 2000, the illiteracy rate for populations aged 15 years and older declined from 37% to 21%. In the least developed regions, illiteracy rates were cut in half in this period, from 53% to 27% (although 23 countries, mostly in sub-Saharan Africa, still show illiteracy rates above 50%) (UNESCO [2000]). *World Education Report. The Right to Education: Education for All throughout Life*, pages 37-38, Figures 2.3 and 2.4. Paris: UNESCO Publication).

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3 UNESCO, op cit., pages 63-64, Figure 3.5.

4 UNESCO, op cit., p. 164, Table 10, and p. 132, Table 2m.

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