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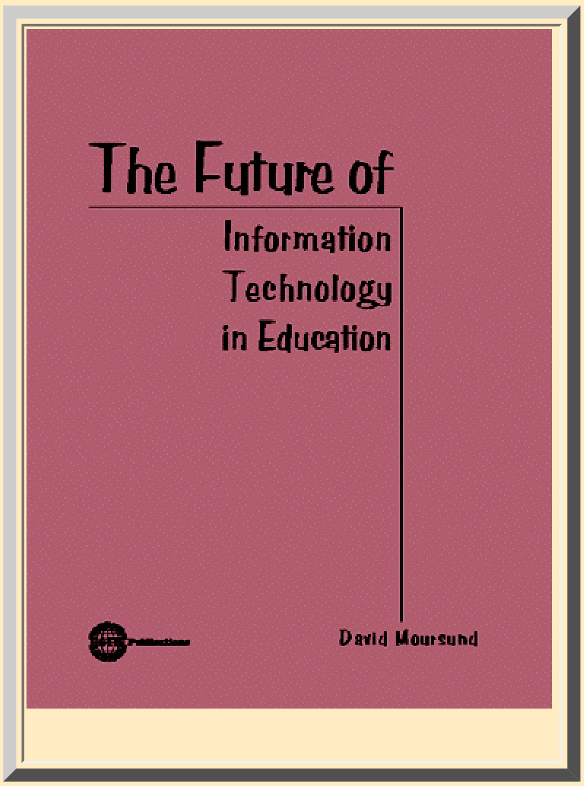

The Future of Information Technology in Education
An ISTE Publication

Return to Cover Page

About the Author

- **Dr. David Moursund** has been teaching and writing in the field of computer technology in education since 1963. He was the chairman of the Department of Computer Science at the University of Oregon from 1969 to 1975. He is now a professor in the College of Education at the University of Oregon. Dr. Moursund has authored or coauthored more than 30 books and numerous articles on computer technology in education.

  In 1979, he founded the International Council for Computers in Education (ICCE), which became the International Society for Technology in Education (ISTE) in 1989 when it merged with the International Association for Computing in Education. Dr. Moursund is currently the executive officer of ISTE.

Return to Cover Page

From the Publisher

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Return to Cover Page

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Return to Cover Page

Contents Chapter 1 >>>

Preface

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This book is about the future of information technology in K-12 education. It is intended for people who have an interest in how information technology will change and improve education. This includes parents, teachers, school administrators, school board members, legislators, corporate foundations, and educational policy makers.

Some Features of This Book

- Some noteworthy features of this book include:
    - It is relatively short.
    - It contains a number of brief quotes from many different popular press news items. These help paint a picture of current and emerging roles of information technology in our society.
    - While the focus of this book is on education in the United States, quite a few of the examples report on use of information technology outside of the United States. All of the educational systems of the world are faced with the challenge of dealing with the increasing capabilities and availability of information systems.
    - The forecasts are supported by multiple sources of information and forecasting techniques. The Appendix discusses a number of different forecasting methodologies. You can use ideas discussed here if you want to make your own forecasts.
    - Each chapter ends with a few concluding remarks and some recommendations. You can think of these recommendations as "my best professional advice."
    - Chapter 9 discusses long-range strategic planning for technology in education. You can use these ideas to help plan educational changes that you feel are appropriate.

- The References section is extensive and contains brief annotations for each of the items.

Personal Note

- I have been a "computer educator" for more than 30 years. During all of that time I have been optimistic about the future of computer technology in education.

  In retrospect, it is clear that I have been overly optimistic. Educational systems are quite resistant to change. Progress has not occurred as fast as I had thought it would. Still, considerable progress has occurred, and the groundwork has been laid for further progress. It is clear to me that we are just at the beginning of a number of major changes in our educational system that will occur because of continuing progress in information technology.

Acknowledgments

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<<< Preface Contents Chapter 2 >>>

Chapter 1
Introduction

- Many people are unhappy with our current educational system, and they can give lots of reasons for their unhappiness. For example, they point to international comparisons on test scores. Or, they point to large numbers of students failing to finish high school and to many high school graduates who are not sufficiently qualified for beginning jobs.

  A main theme in this book is that our current educational system is not adequately preparing students for the "global village," Information Age world they will be living in as adults. Our current educational system is out of tune with today's Information Age society. There is considerable room for improvement.

  Here are some Information Age buzz words that are part of our everyday world: agent technology; cable modem; cellular telephone; CD-ROM; color laser printer; communications satellite; computer animation; computer-assisted instruction; computer-assisted learning; computer simulation; desktop conferencing; desktop publication; desktop presentation; digital camera; digital music; digital radio; digital television; direct-broadcast satellite; distance education; DVD-ROM; edutainment; fax; fiber optics; floppy disk; geographic information system; global positioning system; High Definition Television; information highway; laser printer; local area network; hypermedia; hypertext; Internet; Java; laser disc; mainframe computer;

microcomputer; minicomputer; modem; multimedia; network; optical disk; personal digital assistant; software; super computer; video telephone; virtual reality; wide area network; and World Wide Web.

Information technology is everywhere, and it is certainly changing our world. Some of the change is well summarized by the expression "Global Village" coined by Marshall McLuhan. The technology is connecting people from throughout the world. The technology has provided a new and powerful tool, and people throughout the world face the task of learning to use this tool.

Marshall McLuhan is also known for his statement, "The medium is the message." Information technology is a new medium, a new way of representing, communicating, and working with information. Information technology is both an important area of study in its own right and also a tool that is being integrated into the everyday lives of more and more people.

To date, however, the impact of information technology on our K-12 educational system has been minimal. It isn't that our schools don't have computers and other information technology facilities. Rather, they don't have enough, and much of what they do have is not used to their advantage. Students and teachers lack basic information technology knowledge and skills. The curriculum, instruction, and assessment do not adequately make use of the capabilities of today's networked information systems.

Computer Use Outsdie of K-12 Schools
Educational Change
Initial and Subsequent Impact of New Technology
Some Key Educational Questions
Conclusions and Recommendation

Computer Use Outside of K-12 Schools

- Much of the pressure for integrating information technology use in schools is coming from outside the school system. Parents, politicians, and business people are making the observation that computers are routinely used outside of schools, and asking why they are not more routinely used in schools.

  In the United States, more than 55% of adults make use of a computer at work and/or at home. Business and industry in the United States have spent hundreds of billions of dollars acquiring information technology, training their employees, and adapting their methods to take advantage of the technology. By and large, if a worker's productivity can be increased by access to such technology, the technology is made available.

  Computers are now relatively common in households. There are more computers in the homes of our students than there are in schools. As the following brief news items indicate, home sales of microcomputers are a large and growing business.

  - **PC Homes Up 16% From Last Year**

    The number of households that own personal computers grew by 16% last year, according to a new survey by Computer Intelligence Infocorp., which interviewed 11,500 PC users. That puts the total percentage at 38.5% of U.S. homes that have one or more PCs. "We were surprised to see penetration levels jump five percentage points," says a Computer Intelligence analyst. "That is a very healthy increase." Recent buyers tended to be older and less-affluent Americans. The growth in PC ownership among households making $10,000 to $30,000 is up nearly 25%, to a range between 10% and 30% of the total, and about 20% of households headed by people over 60 now contain a PC.

    Wall Street Journal. (1996, May 21). p. B10.

Home Sales Continue to Grow

Forrester Research predicts that the percentage of homes with PCs will push past 50% by 2001, spurred by lower priced and easier-to-use machines. "(There's) nothing that's going to blow the lid off and bring in 60% penetration," says an analyst for International Data Corp. "I think the market will continue to be an upgrade and replacement market."

Investor's Business Daily. (1997, January 7). p. A8.

Our Love Affair With E-Mail

Forrester Researcher says 15% of the U.S. population now uses e-mail, up from 2% in 1992. And they predict that within five years, that number will rise to about 50%. "It's the most popular online activity," says a Forrester analyst. "Growth will be fueled by the increase in home PC penetration and the growth of Internet access in corporations. Furthermore, the emergence of personalized services and tools that let ordinary people combine graphics and attachments will help make e-mail a preferred means of communication."

Investor's Business Daily. (1997, January 15). p. A6.

The rapid growth in use of information technology is a worldwide phenomenon. For example, the percentage of households in New Zealand that have microcomputers is considerably above the U.S. level. Sales of microcomputers in some of the less industrialized countries of the world, such as Brazil and China, now exceed a million microcomputers per year.

In the industrialized nations of the world, the Industrial Age is giving way to the Information Age (now sometimes called the Information and Communications Age). Many of the non-industrialized nations are attempting to leapfrog into the Information Age. Job requirements are changing. Many jobs are disappearing, while many others are being created. Lots of people find the pace of change to be overwhelming. And, the pace of change will continue.

The worldwide computer electronics industry is huge, has been growing rapidly for many years, and forecasts are for continued rapid growth.

-

Emerging Markets for PCs

A Dataquest report indicates that between 1992 and 1994 PC sales rose 44% in the U.S. (to $37 billion), contrasted with a more modest 22% in Europe and a dramatic 83% in emerging markets. China and South Korea are each now buying more than a million PCs a year, and Brazil, India, Thailand, Malaysia and Indonesia will soon follow their example.

Forbes. (1995, December 4). p. 256.

The Most Well-Connected Country in the World?

In Finland there are 62 Internet host computers for each 1,000 people, twice the proportion in the U.S. Nearly 30% of Finnish homes have portable computers and about 60% have access to the Internet.

New York Times. (1997, January 20). p. A1.

Worldwide Chip Sales Up 40%

Revenue from sales of semiconductors rose 40% last year, to $154.7 billion, according to preliminary results compiled for a new study by Dataquest. North American chip makers' lead over Japanese competitors narrowed to 0.3%, down from 1.2% last year-with North American suppliers claiming 39.8% of the market to Japan's 39.5%. Dataquest predicts healthy sales in the future, fueled by global demand for PCs and corporate networks, and estimates chip sales will top $300 billion by the year 2000.

Wall Street Journal. (1996, January 9). p. B2.

Notice the specific references to the global demand for personal computers and computer networks. Both the demand for-and the capabilities of-these systems have been growing rapidly for several decades. Now, ask yourself: "How is this going to affect education?" This book explores a variety of answers. One piece of the answer lies in distance education, as suggested by the following brief news items.

- **African Virtual University**

  The African Virtual University, sponsored by the World Bank, is providing engineering students the opportunity to take courses in electrical engineering from a professor at the University of Massachusetts at Amherst. The professor's stateside course is videotaped and transmitted via satellite to participating institutions in Ethiopia, Ghana, Tanzania, Uganda and Zimbabwe. The professor is available by telephone three times a week to answer questions that the on-site instructor can't answer, or for which clarification is needed. Eventually, the African Virtual University will be available in more than 40 countries on the African continent.

  Chronicle of Higher Education. (1997, January 17). p. A24.

  Western Governors University

  The new Western Governors University has decided to establish its corporate offices in Salt Lake City, and its academic operations in Denver-the capitals of the states represented by its most visible backers, Gov. Mike Leavitt of Utah and Gov. Roy Romer of Colorado. The university's legal counsel says he expects WGU to complete incorporation early this year, and plans to seek approval from all three of the regional accrediting bodies with jurisdiction in the participating states. Officials hope to begin offering classes next fall.

  Chronicle of Higher Education. (1997, January 10). p. A27.

We are at the beginning of a major revolution in higher education throughout the world, because distance education is bringing major competition into education. We will mention and illustrate this from time to time throughout the book, although the main emphasis is on K-12 education. The following news item is a prediction that distance education will drastically change higher education during the next 30 years. As we will see later in this book, distance education and other technology-based instructional delivery systems are already impacting K-12 education, and this impact will increase.

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  Drucker Says "Universities Won't Survive"

  Renowned management consultant and author Peter Drucker says: "Thirty years from now the big university campuses will be relics. Universities won't survive. It's as large a change as when we first got the printed book. Do you realize that the cost of higher education has risen as fast as the cost of health care? ❩ Such totally uncontrollable expenditures, without any visible improvement in either the content or the quality of education, means that the system is rapidly becoming untenable. Higher education is in deep crisis ❩ Already we are beginning to deliver more lectures and classes off campus via satellite or two-way video at a fraction of the cost. The college won't survive as a residential institution. "

  Forbes. (1997, March 10).

Educational Change

- There is no doubt that information technology will cause major changes in our educational system. Already, we can find abundant examples of some of the types of changes that we can expect to become widespread. For example, many schools require all of their students to achieve basic competency in using a word processor and other computer tools such as spreadsheets, databases, and graphics. Graphing calculators-some that are nearly full scale computers-are routinely used in many high school math courses.

  The World Wide Web is a very powerful change agent. It provides an interactive, multimedia access to information sources throughout the world. Surfing the Web and creating interactive hypermedia materials for publication on the Web are common activities of many students.

  The Web was created by Tim Berners-Lee in 1991, and it is still in its early childhood. However, we can already begin to see what Web-type connectivity can contribute to business, government, and education. When asked to comment on the future of the Web, Tim Berners-Lee stated:

- *I hope that the notion of having a separate piece of software called a "browser" will disappear. A browser is something that (a) only allows you to read and not write, and (b) is a single window on the world. Instead, your entire screen should be a window on the information world, with a small part representing what's on your local "desktop." Browser and operating-system interfaces will become so interlinked that they will, for all practical purposes, become one.*

Technology Review. (1996, July).

Substantial progress is already being made toward fulfilling Berner-Lee's hopes. Browsers are being built into computer operating systems in a manner that facilitates routine Web access as one makes use of other computer applications.

Computer technology in education has become important enough so that it is now a national political issue. In an October 10, 1995, speech, President Clinton said:

- *We are going to work together so that every child in America is technologically literate by the dawn of the 21st Century.*

Clinton has outlined "four pillars" for his program of technology in schools. Notice that the second pillar focuses on connectivity.

1. **Computers.** Equipping every classroom with modern computers and learning devices, accessible to every student.

2. **Connections.** Connecting every classroom in America to one another and to

the outside world.

3. **Educational Content.** Providing a rich variety of engaging instructional materials and courseware.

4. **Teacher Training.** Ensuring that all teachers have the training and assistance they need to make full use of these new technologies.

Initial and Subsequent Impact of New Technology

- Initially, most new technology is used to do essentially the same thing as the old technology, but to accomplish a task or solve a problem in a better way. This impact can be thought of as an amplification of what is already being done. The initial new technology may not be a significant improvement on the old. The early horseless carriages were in many ways not as good as a horse and carriage. For example, a horse can follow the road or a path with little help from the driver. However, the horseless carriage had the potential to be significantly better than horses in accomplishing the task of moving people and materials.

  For an invention that comes into widespread use, we often see three stages of adoption and use. First, the invention is improved to the point where it is clear that it has significant advantages-that is, it becomes an effective amplification-over the previous technology and methods of solving a particular problem or accomplishing a particular task. Horseless carriages (cars) increased in reliability and speed.

  Second, the infrastructure needed for widespread use of the invention begins to develop. Cars became more useful and more widely used as an infrastructure of paved roads, filling stations, and repair people was developed.

  Finally, second-order effects (most often these are not anticipated) begin to emerge. Use and impact of the invention moves beyond amplification. The outward spread of cities and shopping malls were second-order effects of cars, as was air pollution due to exhaust fumes. Other second-order effects included development of super highways, a trucking industry, and a worldwide petroleum industry.

There are many first and second-order effects in information technology. Here are some examples that are particularly relevant to education.

- The use of a computer to do word processing is a first-order effect, an amplification of the electric typewriter. The teaching of typing in schools has given way to the teaching of keyboarding and word processing. However, typing was most often taught at the high school level. Students now need to learn keyboarding and word processing at the elementary school level. This has created problems that were not initially anticipated as microcomputers began to come into schools. The problems are an example of a second-order effect.

- Desktop publication is another second-order effect that has emerged from microcomputers and word processing. A whole new industry has developed around desktop publication. Desktop publication has proven to be a challenge to our K-12 educational system because few teachers initially had the knowledge and skills needed to help students learn this new field of study.

- The use of computers to insert simple graphics into a word processed document is a first-order effect. The use of a computer to create and/or edit animation, photographs, sound, and video are all second-order effects. Interactive hypermedia is another second-order effect. As information technology has continued to improve, it has become possible for elementary school students to develop hypermedia projects. The challenge to elementary school teachers is obvious. Information technology in K-12 education has had the second order effect of overwhelming our inservice educational system. Curriculum, instruction, and assessment are not changing nearly as rapidly as the technology that is being provided to students.

- The use of a computer to do payroll computations is a first-order effect. The spreadsheet is a second-order effect. The spreadsheet facilitates the development of computer models of a business, and the use of these models to do forecasting and to examine "What if?" types of questions. Initially, the spreadsheet was viewed as an accounting tool, so its use was gradually integrated into high school business courses. However, spreadsheets are a tool useful in many different academic disciplines, even down into the elementary school. The second-order effect of this widespread usefulness has proven to be a challenge both to curriculum developers and to the teachers who attempt to implement curriculum that makes use of spreadsheets.

- The use of an electronic calculator or a computer to do simple mathematical and scientific calculations is a first-order effect. By the late 1970s, calculators were reliable enough and inexpensive enough so that some schools were making routine use of them. We are now seeing the second-order effects of major changes in the curriculum being brought about by calculators, and calculator use being allowed on college entrance exams. Eventually, we will see computers thoroughly integrated into the curriculum and being used in national assessments.

- The use of a computer to directly gather data from a scientific experiment is a first order effect. Use of a computer to control the experiment is a second order effect. Laboratory instrumentation has become increasingly sophisticated. Instruments now exist that can quickly and automatically solve problems that used to take researchers many hours of time.

  The microcomputer-based laboratory (MBL) as a teaching and learning tool is another second-order effect. Many students at the middle school level and higher are learning science in a hands-on approach that includes using sophisticated but inexpensive instrumentation.

- A computer can solve many of the types of problems that occur in mathematics, science, and engineering. Computers and sophisticated calculators quickly achieved the first-order effect of replacing paper and pencil, slide rule, and simple calculators to do these computations. But, computers make possible the three dimensional mathematical modeling of molecules, airplanes, nuclear explosions, and other complex problems studied by scientists and engineers. These second-order effects are changing what students need to learn to be effective scientists and engineers.

- The use of a computer to do electronic mail is a first-order effect. The World Wide Web is a second-order effect. Teams of people working together via desktop conferencing and groupware are another second-order effect. Our schools are just beginning to develop the curriculum, instruction, and assessment needed for an environment in which students have routine access to the Web. Few students are learning to learn and to solve problems in a groupware environment.

- The electronic encyclopedia on a CD-ROM is a first-order effect. The emerging Web-based global library is a second-order effect. In the past, elementary school teachers faced the challenge of helping students to gain a functional level of knowledge and skill in using a card catalog by the time they left the elementary school. Now, elementary school teachers face the more difficult challenge of helping students to make effective use of the global library.

- The use of a computer to automate flash cards is a first-order effect. Immersion of a learner in a highly realistic and interactive computer simulation or virtual reality designed to facilitate learning is a second-order effect. Similarly, the use of e-mail to facilitate receiving and sending in lessons in a distance education course is a first-order effect. Interactive Web-based distance education courses are a second-order effect. Such aids to instruction and learning will eventually lead to major changes in roles of teachers in schools. Some of these potential changes are discussed later in this book.

- The use of computers to digitize, store, and play back sound is a first-order effect. The use of computers to create and edit sounds is a second-order effect. The music industry has been greatly changed by computer technology. The facilities needed to compose, edit, and play electronic music are now available to many school children, even at the elementary school level. This presents a significant challenge to our music education system.

- Manufacturing, servicing, and selling computers are all new jobs created by the computer industry. These new jobs can be considered as a first-order effect. A second order-effect has been changes at the middle management level of employment. Millions of jobs have been lost. Another second-order effect is that worldwide networking facilitates worldwide competition for an increasing number of jobs. If a job can be accomplished by telecommuting, then perhaps the worker can live 10,000 miles from company headquarters. The second-order effect in education is a gradual emergence of worldwide standards. Students throughout the world need an education that adequately prepares them for jobs that exist throughout the world.

The distinction between first-order and second-order levels of information technology use is not a fine dividing line. The second-order levels of use tend to represent major transformations in the nature of how information is processed, how problems are solved, and how people communicate.

Once we understand third-order effects, we will begin to move to still higher levels. For example, consider use of information technology in implants to restore partial hearing or partial sight to certain hearing impaired or visually impaired people. It seems clear that eventually we will be doing brain implants and/or other types of direct neural connectivity of information storage and processing devices. Early work on restoring sight focused on a direct brain implant of a 2-inch-square plastic grid of electrodes. Now, progress in miniaturization of electronics is allowing a different approach.

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The Gift of Silicon Sight

Electronics has come a long way. Now, scientists in North Carolina are working on a tiny chip to be implanted in the eye, not in the brain. The chip is just 2 millimeters square-yet will eventually have a 250-by-250 grid of electrodes. That should provide enough detail to read a newspaper, says Wentai Liu, an electrical engineering professor at North Carolina State University.

Business Week>. (1997, January 27). p. 101.

Ubiquitous computing-computers everywhere-is another possible third-order effect that is beginning to emerge. A later section in this book discusses the possibility of a typical household containing many hundreds of computers networked together. Most would be of modest capability, such as a very tiny computer and transceiver built into the spine of a book.

The majority of current educational uses of information technology at our K-12 schools is at the first-order (amplification) level. While some second-order effect uses are creeping into our schools, the depth and breadth of such use so far has been modest. The best is yet to come.

Some Key Educational Questions

- This book contains a number of forecasts about the continued growth of the information technology industries. These forecasts are analyzed from an educational systems point of view. The analyses form the basis for a number of predictions about the future of information technology in schools. These predictions provide support for a number of recommendations given in this book-things that our schools should be doing right now.

  Some of the questions discussed in this book include:

  - What will education be like when most students have easy telecommunications access to people (including other students), major libraries and museums, and other information sources throughout the nation and world?

  - What will education be like when most students have easy access to computer-assisted instructional materials and to distance education courses that cover far more than all of the conventional curriculum courses offered in their school-and these are available at a time and place (including home) that is convenient to the user?

- What will educatioqn be like as artificially intelligent computer systems steadily grow in capability and gain the capability of solving many of the problems that students are currently learning to solve using "by-hand" methods?

- How will education be changed as the second-order levels of information technology use become thoroughly integrated into curriculum, instruction, and assessment?

Such questions are not easily answered. However, it is now possible to make informed guesses, providing answers rooted in a good understanding of our educational system and of the steadily increasing capabilities of information technology.

Conclusions and Recommendation

- Over the past two decades, business and industry have struggled to adapt to the changes made possible by information technology. Millions of blue- and white-collar workers have lost their jobs. Small companies have grown into large companies. Large companies have downsized. Merger mania continues. Entire new industries have developed, while other industries have disappeared.

  We can expect similar disruptions and changes in our educational system. We are just at the beginning of these changes. Accurate forecasts of where we might be headed, accompanied by careful long-range strategic planning, can make the change process easier and more comfortable.

Return to Cover Page

<<< Chapter 1 Contents Chapter 3 >>>

Chapter 2

The Forecasting Business

- It is easy to make predictions or forecasts about the future. However, it is not easy to have a high level of accuracy in these forecasts. This chapter begins with a number of forecasts that people have made in the past. You will be amused by their lack of accuracy. These examples are designed to make the point that it is difficult to predict the future of technology.

  This chapter also contains some information about the worldwide electronics and telecommunications industry. The information indicates that these huge industries are planning to be still larger in the future. The people who are running these companies are predicting a continued very rapid growth in computer and communications technology throughout the world. Their commitment of major resources is shaping the future. One way to accurately predict the future is to create the future.

Some "Amusing" Forecasts

- What follows are a number of "amusing" quotations. Each section begins with a quote and is then followed by a brief analysis. You may want to attempt to put yourself in the shoes of the people who made these statements. What was their knowledge and world view that led to such poor forecasts? Are today's forecasters producing equally poor forecasts?

Medicine

- *Louis Pasteur's theory of germs is ridiculous fiction.*

(Pierre Pachet, professor of physiology at Toulouse, 1872.)

The "theory" of germs represented a major step forward in medicine. Such major breakthroughs in science do not occur very often. The theory of germs led to significant changes in medical practice. Nowadays, even young children are taught to wash their hands and to "cover" their sneezes-to avoid the spread of germs.

The Telephone

- *This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us.*

(Western Union internal memo, 1876.)

Samuel Morse invented the telegraph in 1842 and its use gradually spread to much of the world. Using Morse code, printed messages could quickly be sent over long distances. The telegraph technology was well established by the time that Alexander Graham Bell invented the telephone in 1876. Western Union was a major supplier of telegraph services in the United States.

When a new technology competes with an existing technology, it is not always easy to see which will win. Who could have foreseen a person driving a car down a freeway, carrying on a telephone conversation with a person flying across an ocean on the other side of the world?

Motion Pictures

- *Books will soon be obsolete in the schools. ❱ Scholars will soon be able to instruct through the eye. It is possible to touch every branch of human knowledge with the motion picture.*

(Thomas A. Edison, 1913.)

- *I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks.*

(Thomas A. Edison, 1922.)

Thomas A. Edison was a prolific inventor and was very successful in developing companies to produce and market his inventions. He is considered to be one of the inventors of the motion picture. The two quotes give his insights into how the motion picture would revolutionize education. He was wrong.

A number of years later, similar predictions were made about television, and then about video tape. It seems clear that Edison had little insight into the complexities of an educational system. Education is far more than an information delivery system. We must keep this in mind as we examine some of the possible impacts of information technology on our educational system.

The Radio

- *The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?*

(David Sarnoff's associates in response to his urgings for investment in the radio in the 1920s.)

The first commercial radio station began broadcasting in 1920. Few people had a clear vision of the future of commercial radio broadcasts. For example, who would have thought that there would be radios in cars or that people would carry portable radios-even when jogging?

Electronic Digital Computers

- *I think there is a world market for maybe five computers.*

(Thomas Watson, chairman of IBM, 1943.)

Electronic digital computers based on vacuum tube technology were simultaneously developed in England, Germany, and the United States beginning in the late 1930s. The Electronic Numerical Integrator and Calculator (ENIAC) was built in the United States and became operational in January of 1946. It is considered to be the world's first fully operational, general-purpose electronic digital computer.

The ENIAC was designed to do numerical calculations-it was an amplification of the desktop calculating machine. It could do the work of several hundred people working with electric calculators. In 1943, Thomas Watson did not envision very many problems that required such massive amounts of calculation.

The Transistor

- *Computers in the future may weigh no more than 1.5 tons.*

(Popular Mechanics, forecasting the relentless march of science, 1949.)

The transistor was invented in 1947. At that time, there were less than a dozen computers in the whole world. These were room-filling machines, each employing many thousands of vacuum tubes. In many electronic circuits, a transistor can replace a vacuum tube. Even the very first transistors were much smaller than vacuum tubes and consumed much less electrical power.

The invention of the transistor was a major breakthrough in science. Its inventors were awarded the Nobel Prize. Further research on transistors led to the invention of the integrated circuit. The integrated circuit has made transistors much smaller and much cheaper. A single integrated circuit-smaller than a dime-can now contain many tens of millions of transistors. Worldwide production of transistors is now well in excess of a sixth of a million transistors per person per year, for every person on earth. This progress in chip technology has made possible laptop and palmtop computers.

Microprocessor

- *But what) is it good for?*

(Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.)

By 1968, timeshared computing was a well-established technology. Terminals could be directly wired to a timeshared computer, or the connection could be made over a telephone line. In 1968, timeshared computing using a 10 character per second (uppercase only) Teletype terminal cost about $40 per hour.

The first integrated circuit was developed in 1958, and the first single-chip central processing unit (the first microprocessor) was developed in 1971 for use in a calculator. At that time, and for years to come, IBM was firmly committed to the mainframe computer. The Advanced Computing Systems Division of IBM did not envision the very rapid progress that would occur in microprocessor technology.

The Apple Computer

- *So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.'*

(Apple Computer Inc. founder Steve Jobs on attempts to get Atari and Hewlett-Packard interested in his and Steve Wozniak's personal computer.)

Steve Jobs and Steve Wozniak started Apple Computer, Inc. in 1975. A number of other start-up companies and already well-established companies began manufacturing microcomputers at about the same time. This all happened because of the development of microprocessors powerful enough to be used in a general-purpose computer.

Personal Computers

- *There is no reason anyone would want a computer in their home.*

(Ken Olson, president, chairman and
founder of Digital Equipment Corporation, 1977.)

Digital Equipment Corporation (DEC) produced the world's first minicomputer in 1960. Although DECs first minicomputer, the PDP-1, cost $120,000, it was the start of a major trend away from mainframe computers toward smaller sized, lower priced computers that could be used in a room that was not air-conditioned. DEC was slow to realize that microcomputers would eventually have capabilities that rivaled minicomputers at a much lower price. The relatively low costs of microcomputers have opened up school use and home use as major computer markets.

Many of the future-looking insights illustrated in this section were made by people who were well situated to help shape the future. In most cases, these people eventually came to realize that their initial forecasts had been incorrect. They then made significant contributions to implementation of the technologies they had first denigrated.

At the same time that some well-situated business people are delaying acting on possible major new technologies, others are making major financial commitments to the new technologies. By doing so, they shape the future. Consider the following quote from Steve Jobs, one of the founders of Apple Corporation:

- *When I went to Xerox PARC in 1979, I saw a very rudimentary graphical user* *interface. It wasn't complete. It wasn't quite right. But within 10 minutes, it was obvious that every computer in the world would work this way someday. And you could argue about the number of years it would take, and you could argue about who would be the winners and the losers, but I don't think you could argue that every computer in the world wouldn't eventually work this way.*

Wired. (1996, February). p. 102.

Steve Jobs was able to translate these insights into the creation of the Macintosh computer, which first became available in 1984. Notice the time lag. A rough rule of thumb in the electronics industry is that it takes 5 years to bring an idea from the research laboratory into the commercial marketplace.

Worldwide Growth in Computing Power

- Computer technology is no longer a new invention. The year 2001 will see us celebrating 50 years since the commercial introduction of the UNIVAC-the first mass produced computer. Computer electronics is now a huge and still rapidly growing industry. How rapidly will this market continue to grow? Here is one forecast that looks 20 years into the future.

Growth in the Electronics Industry

  - *Vladi Catto, chief economist at Texas Instruments Inc., says the industry might expand by 20% a year for the next two decades. By comparison, since TI made the world's first microchip [integrated circuit] 36 years ago, the industry has averaged 15% annual gains.*

Business Week. (1996, January 8). p. 95.

A 20% a year growth rate is more than a doubling in 4 years. (If you could earn 20% interest on your money, compounded annually, $1 would grow to $2.07 in 4 years.) Two decades of this pace of change would represent a growth by a factor of more than 38 in the annual dollar sales of the electronics industry.

The 20% yearly growth rate forecasted by Vladi Catto is a forecast of increased dollar sales. The number of transistors and other electronic components that can be purchased for a given dollar amount has continued to decrease rapidly over the years. For example, a megabyte of chip memory has decreased in price from $550,000 25 years ago to well under $10 today. This indicates how rapid this pace of change has been. People in the electronics industry have gotten used to the idea that the amount of computing power that one can buy for a given amount of money tends to double in less than 2 years. This rapid pace of price to performance improvement has been going on for several decades.

Now, let's put these two types of change together. Over a period of 4 years, the dollar value of worldwide productivity of chips doubles. Meanwhile, the amount of computing power that a dollar will buy doubles twice. This means that at the end of 4 years, the worldwide productivity of computing power has gone up by a factor of eight. This pace of change has been going on for many years and it appears likely to continue for many more years to come.

Growth in the telecommunications industry is a key and essential companion component of growth in the electronics industry. It is a combination of computing power and connectivity that is changing the way that the world does business and that is going to change our educational system.

Fiber optics, communications, cellular telephones, and progress in data compression (reducing the amount of storage that is required for a document or a video also reduces the time needed to transmit it over a telecommunications system) are all making rapid progress.

Fiber Optic Link Around the Globe

- *A consortium led by AT&T Submarine Systems in the U.S. and NDD Submarine Cable Systems in Japan has begun a $1.5 billion project ("Flag," or Fiberoptic Link Around the Globe) to lay undersea fiber optic cables from England to Japan, with landing points in Europe, the Middle East, Africa and Asia, in order to provide 120,000 64kbps circuits. About 50 telecommunication companies from around the* *world have agreed to purchase capacity on the cable.*

Financial Times. (1996, January 19). p. 4.

A 64 kilobits per second circuit can carry a high quality telephone conversation. The Flag project will support 120,000 simultaneous long distance telephone calls. However, much faster transmission rates (a much greater bandwidth) are needed for dealing with large amounts of data, such as graphics.

Boosting Internet Bandwidth

- *Internet service provider iStar beefed up the capacity of its network with new links between Toronto, Montreal, Ottawa and the American portion of the Internet and increased its Internet bandwidth 28 times.*

Toronto Financial Post. (1996, January 5). p. 39.

Another Global Telecom Alliance

- *Telecommunications companies Deutsche Telekom, France Telecom, and Sprint are forming an alliance called Global One in order to provide worldwide voice, data and video services for corporate clients; international consumer services (such as calling cards); and international transmission and support to other international carriers. Global One will be competing against two previously formed global alliances: Uniworld, formed by AT&T and four European telecom operators; and Concert, formed by British Telecommunications and MCI.*

Financial Times. (1996, February 1). p. 16.

AT&T Plans $9 Billion Upgrade

- *AT&T will invest up to $9 billion this year in upgrading its communications network-almost double what it usually budgets for such improvements. About $5 billion of that will go toward the business-markets division to beef up the backbone network, improve fast packet technology, and enhance voice and local services.*

Information Week. (1997, March 10).

These brief news items indicate that the major telecommunications companies are investing heavily to support continued rapid and worldwide growth of telecommunications.

The leading electronics and telecommunications companies of the world are committing huge amounts of resources to increase their capacities. This huge commitment of resources is shaping the future. That is, we can base a number of our forecasts for the future uses of electronics and telecommunications on an expectation of continued rapid increases in availability of computing power and telecommunications capacity.

We conclude this section with two predictions about the future of networking. The first is from Nathan Myhrvold, Senior Vice-President, Advanced Technology, Microsoft. Microsoft is a major force in the world's computer software industry. The second is from Netscape president Jim Clark. Netscape is a world leader in the development of World Wide Web browsers.

As Big as Gutenberg

- *This [global networks such as the Web] is going to be at least as big as Gutenberg. Soon ❱ digital networks will let people buy anything, meet anyone, and conduct any business over a virtual marketplace. Digitized money will transform regional* *banking into a global exchange. Third World countries will enter markets that could never be dreamed of before.*

(Nathan Myhrvold, senior vice-president, advanced technology, Microsoft.)
Business Week. (1994, November 18). p. 108.

Internet is "Fundamental Change" in Telecom

- *Netscape president Jim Clark says: "I've been talking to the telecommunications companies and telling them that it's [global networks, such as the Web] the future. It represents the first fundamental change since the telecommunications system was invented. The biggest change up to now was when the telephone moved from a rotary dial to Touch-Tone) that's really a small change compared to this."*

Atlanta Journal-Constitution. (1996, June 4). p. F3.

Conclusions and Recommendation

- This chapter contains a number of examples of forecasts or predictions that proved to be wrong. Such examples serve as a warning to people who may want to commit major resources based on forecasts and predictions. "Off the top of the head" predictions are easy to make. Long-range strategic planning based on such predictions is apt to be totally useless. The obvious recommendation is "Look before you leap."

  This chapter also contains a number of brief news items indicating that leaders in the electronics industry are investing heavily in the future of their field. They are building a great deal of increased capacity. They believe that the world is just at the beginning of really massive growth in its use of computer and communications technology. These large investments in capacity building are based on careful long-range strategic planning. The companies making these large investments are shaping the future.

There is every reason to believe that we are just at the beginning of massive growth in the number and nature of computer facilities and telecommunication facilities that are in use throughout the world. The total worldwide amount of computing power and connectivity bandwidth could each grow by a factor of 1,000 or more during the next two decades. (A more detailed analysis of this assertion is given in Chapter 6.)

The message for our educational system is clear. Students need to be prepared for adult life in a world that has immense amount of more information technology than is currently available.

The next chapter contains a brief history of our educational system. The emphasis is on how changes in technology have fostered changes in education in the past.

<<< Chapter 2 | Contents | Chapter 4 >>>

Chapter 3

Education Systems Change Over Time

- This chapter contains a very brief history of education in the United States. The emphasis is on how education has changed in the past; the suggestion is that it will change in the future. The chapter includes a specific focus on computers as an aid to both communication and thinking. Such uses of information technology underlie major changes that will occur in our educational system.

Overall Goals of Education

- David Perkins' book (1992) contains an excellent overview of education and a wide variety of attempts to improve our educational system. He analyzes these attempted improvements in terms of how well they have contributed to accomplishing the following three major goals of education:

    - Acquisition and retention of knowledge and skills.
    - Understanding of one's acquired knowledge and skills.
    - Active use of one's acquired knowledge and skills. (Ability to apply one's learning to new settings. Ability to analyze and solve novel problems.)

  These three general goals-acquisition, understanding, and use of knowledge and skills-help guide formal educational systems throughout the world. They provide a solid starting point for the analysis of any existing or proposed educational system.

  The next three paragraphs expand on the three goals stated by Perkins. These paragraphs capture the essence of changes that Perkins, your author, and many others feel are needed in our educational system.

    - **Acquisition and retention.** The totality of human knowledge is increasing exponentially. Estimates of the doubling time vary, with some people suggesting a doubling of knowledge every 5 years, and some suggesting an even shorter doubling time. The amount of knowledge that one can acquire and retain is a very tiny fraction of the totality of human knowledge-and this fraction is rapidly decreasing. An alternative to trying to acquire more information is to develop the skills of a research librarian. Learn to make effective use of the emerging global libraries that can be accessed by use of computer networks.

- **Understanding.** Rote memory is no substitute for understanding. Similarly, the ability to retrieve information is no substitute for understanding what one retrieves. Our educational system must substantially increase its emphasis on understanding and on higher-order thinking skills.

- **Active use of knowledge and skills.** Information technology in schools empowers students. Given appropriate opportunities and facilitation, students can learn to make second-order effect uses of a wide variety of information technology. Thus, students can accomplish tasks and solve problems that were beyond the capabilities of adults before the information technology became available. Students can address real-world problems and produce useful results.

Education in the United States

- July 4, 1776, was the date of the signing of the Declaration of Independence. It was the dawn of a new nation-the United States of America. At the time of the Revolutionary War, the United States was an agrarian country. Fully 90% of the people lived and worked on farms.

  Thomas Jefferson was one of the main writers of the Declaration of Independence. He went on to become the third president of the United States. He was a broadly educated man, an inventor, and a visionary.

  One of Jefferson's visions was for a greatly improved educational system. In his home state of Virginia, he envisioned and worked toward an educational system that included primary schools that were readily accessible to students. In his plan, 3 years of grammar school would be available to all citizens, with the state paying the tuition for families that could not afford the tuition. (Slaves were not considered to be citizens. Note also that the intent was that the schools would only be free to those who could not afford tuition charges.)

  Students could continue beyond the 3 years of schooling, at their families' expense. In addition, the state would pay the tuition for a modest number of *boys* that displayed great academic potential. These ideas were far too revolutionary for the time, and they were not implemented.

The next hundred years saw slow but steady progress toward an increasing number of students receiving an increasing amount of education. While a grammar school system was well established, relatively few students progressed beyond that level. In the 1870s the high school graduation rate in the United States was only about 3%. The United States was still an agrarian nation and education at the high school level or above was for the elite.

Indeed, in 1890, well under 10% of high school aged students were actually enrolled in a high school. In 1890 Harvard president Charles W. Elliot noted that of the 352 students admitted to Harvard the previous year, only 97 came from public high schools. Since most of these Harvard students were from the state of Massachusetts-the state that probably had the nation's best public educational system-these data suggest that the public educational system left much to be desired.

However, in the late 1800s, the United States was industrializing. Industrialization brought with it increasing educational demands. Many of the main ideas and components of our current educational system were developed and implemented during that time.

In the years that followed, there was a substantial increase in public secondary school education. States began to fund such systems and established requirements for attendance. People debated how much schooling should be required. They also debated college-preparation types of curriculum versus vocationally-oriented types of curriculum. In those days, college preparation included a substantial amount of studies in Latin and Greek.

The secondary school curriculum that gradually emerged bears a striking resemblance to the secondary school curriculum of today. Although there were no national standards, a relatively common core of courses became available at schools throughout the country. The idea of the Carnegie Unit (a year-long course meeting one period a day) was developed. Many colleges throughout the country began to base college admission on students having successfully completed a number of Carnegie Units of coursework from a basic core of nine different subject areas.

During the past half century, the high school graduation rate in the United States has steadily increased, as has the number of students going on to college. This is also true for much of the rest of the world. Improvements in transportation and communication have made it easier for the educational systems in the various countries to build upon ideas from other countries and to compare themselves to educational systems in other countries. We are seeing the gradual development of worldwide goals and worldwide standards for education.

Reading, Writing, and Arithmetic

- Reading, writing, and arithmetic-the three R's-have long been considered to be the basics of education. Thomas Jefferson understood that even 3 years of grammar school instruction in the three R's can produce a useful level of skills. That is because even a rudimentary level of knowledge and skills in the three R's allows one to make use of knowledge that has been stored in books. That is, one can build on the accumulated knowledge of the writers in solving problems and accomplishing tasks.

  The three R's empower people in a number of different ways. For example:

  - The three R's are an aid to communication.
  - The three R's are an aid to the human mind. They help to overcome limitations of the human mind such as limitations of short-term and long-term memory. (Have you ever tried to do long division in your head?)
  - The three R's have made possible a steady accumulation of human knowledge in a form that people throughout the world can access and use. For example, probably you studied Euclidean geometry when you were in high school. Euclidean geometry is a type of mathematics developed about 2,000 years ago.

It takes a great deal of time and effort to develop a useful level of skills in the three R's. What constitutes a "useful level" has gradually increased over the years. While universal third grade education was considered too revolutionary in Thomas Jefferson's time, it is now totally inadequate. Our formal educational system has a major focus on the three R's that continues even on into college, where most freshmen are required to take writing and math coursework.

Information technology is adding new dimensions to the three R's. Writing with pen and ink is different than writing with a word processor and desktop publication system with a built-in outliner, a spell checker, and a laser printer. This, in turn, is but one step toward developing effective interactive hypermedia documents that make use of text, color, graphics, audio, and video.

Computer-based information systems can be used to store books. However, consider the new dimension that is added when one can store both "how to do it" information and have a computer system that can actually "do it." The handheld graphing calculators that are now commonly used in high school math and science classes provide a simple example. Such calculators contain a large number of built-in functions and can automatically produce the graph of a function. Many such calculators also have a "Solve" key. That is, there is a program built into the calculator that can automatically solve an equation that has been entered into the calculator. Stated slightly differently, the calculator stores information about graphing functions and solving equations-and it can automatically carry out the work of graphing a function or solving an equation. Needless to say, the capabilities of a modern microcomputer far exceed those of such handheld calculators.

Reading, writing, and arithmetic are not about to go away. Instruction in these mind tools will continue to be a central focus in education. However, the environment for learning and using these mind tools is changing. An increasing number of students are learning to use information technology at the earliest grade levels-indeed, many students are learning to use these tools before they enter school. Many students are growing up in computer-rich environments. They have good access to information technology at home, and they have had excellent one-on-one instruction from parents who are computer professionals, or who make routine use of computers at work. It is evident that there is a marked difference between such students and those who are obtaining the modest amount of information technology instruction and use that our schools are currently providing.

Information Technology in Schools

- In 1982, our K-12 schools had approximately one microcomputer or timeshared computer terminal for every 125 students. In 1995, the ratio had improved to approximately one microcomputer per nine students. At the time this book was being written, the ratio had improved to approximately one microcomputer per eight students.

In the past few years, information technology in education has become part of the national political agenda.

Clinton Proposes Computers In All Classrooms

- *In his State of the Union speech this week President Clinton said: "Every classroom in America must be connected to the information superhighway, with computers, good software and well-trained teachers. We are working with the telecommunications industry, educators and parents to connect 20% of the classrooms in California by this spring, and every classroom and library in America by the year 2000." The Department of Education's preliminary cost estimate for the proposal is about $10 billion; a McKinsey & Co. consulting study completed last summer for the National Information Infrastructure Advisory Council estimated the cost for the kind of system proposed by the President (i.e., a computer for every four or five students) to be about $47 billion.*

New York Times. (1996, January 25). p. A9.

It is inevitable that students will be provided with steadily improving computer facilities and connectivity. Although the current pace of change in schools seems slow relative to what has been occurring in business and industry, it is torrid relative to the pace of change that schools are used to. And, there are strong pressures to step up the pace of implementation of information technology in education.

The goals that Clinton has listed are both modest and inadequate. They do not adequately reflect information technology as a natural extension of the three R's. A goal of one computer per four or five students is somewhat like a goal of one pencil and one book per four or five students. The educational benefits that can come from information technology will only occur when students are able to have routine access to the technology, in the same way that they now have routine access to pencil, paper, and books. The goal must be adequate facilities, curriculum, and instruction to move all students into routine second-order level uses of the information technology.

Conclusions and Recommendation

- The educational systems of the world and of the United States have changed substantially over the years. To a large extent, the changes have been driven by changes in science and technology. The movement has been toward ever increasing levels of knowledge and skill for all students.

  The current educational system in the United States is strongly rooted in meeting the needs of an Industrial Age society. However, the United States is no longer an Industrial Age society; it is an Information Age society.

  The typically-suggested changes for technology in schools-for example, the Clinton agenda-are rooted in Industrial Age thinking. This thinking envisions a computer as a tool that one "goes to" and uses occasionally, somewhat like people used to use mainframe computers. The Clinton agenda does not provide for every student to have routine access to powerful computers and high bandwidth connectivity. It does not envision students routinely making second-order level uses of the technology.

  The next chapter contains an overview of computer and communications technology in education.

Return to Cover Page

<<< Chapter 3 Contents Chapter 5 >>>

Chapter 4

Computer Technology in Education

- This chapter provides an overview of how information technology is used in curriculum and instruction. It includes a list of goals for students as well as goals for teacher education.

Overview of Information Technology in Education

- The diagram in Figure 4.1 indicates the main roles of information technology in K-12 education. Although administrative uses are shown as one of the major categories, our focus in this chapter is strictly on instructional uses of this technology.

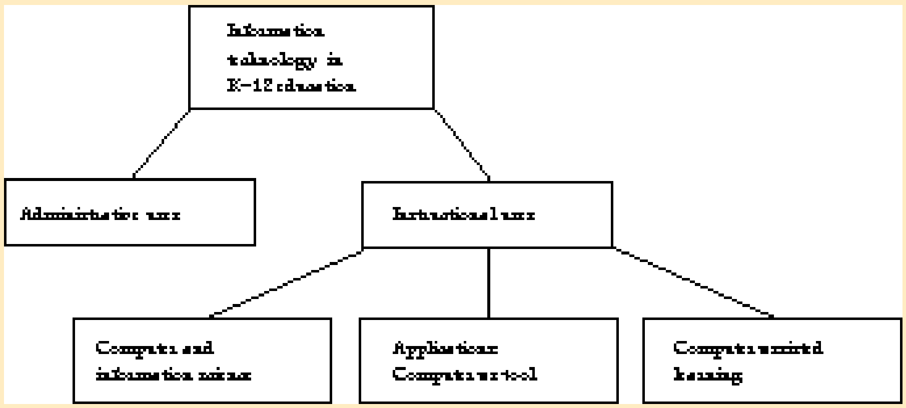

Figure 4.1. Information technology in K-12 education.

Instructional Uses of Information Technology

- As the diagram in Figure 4.2 indicates, the instructional uses of information technology have been gradually merging. Computer-assisted learning materials now include computer-based tools. Computer tools now include "Help" options that are a form of computer-assisted learning. Many computer tools include a built-in programming language that is readily available to the tool user. However, we will discuss the instructional uses as three distinct categories to help clarify the unique characteristics of each.

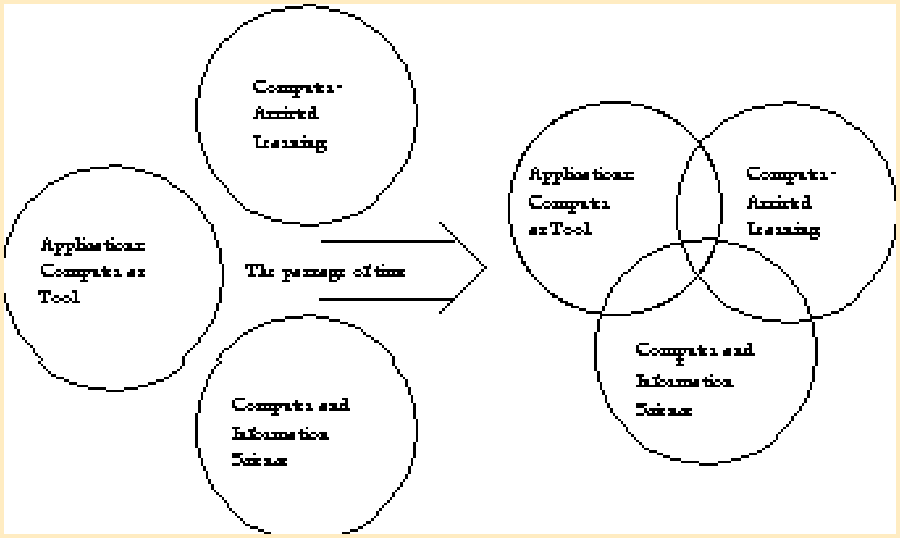

Figure 4.2. A merger of instructional uses of computers.

Computer and Information Science

- Over the past 50 years, computer and information science has emerged as a major discipline of study. Many community colleges, technical institutes, colleges, and universities offer degree programs in this discipline. Current occupations and job openings suggest that many jobs now require a substantial amount of formal post secondary education in the computer field.

  Many of the ideas from computer and information science can be taught at the K-12 level. Thus, all K-12 schools need to make a decision about what to teach from this subject area. Some schools specify elective courses, such as programming languages, an advanced placement computer science course, a robotics course, or an electronics course. Some schools integrate instruction about computer and information science into other curricula. For example, some computer programming might be integrated into mathematics, while some electronics and computer networking might be integrated into physics.

Computer-as-Tool

- The computer is a useful and versatile tool. It can be used to help solve the problems and accomplish the tasks that are at the center of many different academic disciplines. Computer tools for education can be divided into three categories:

  1. Generic tools: Software programs such as word processors, database managers, and graphics packages cut across many disciplines. All of the tools in an integrated package such as ClarisWorks or Microsoft Works are examples of generic tools. A student who learns to use these tools can apply them in almost every area of intellectual work.

  2. Subject-specific tools: There are tools that are designed for a particular academic discipline. Hardware and software to aid in musical composition and performance is an example. Graphic artist and engineering drawing software are additional examples. Many different disciplines have developed hardware and software specifically to meet the needs of professionals. That is, there has been a merger of the discipline and the information technology tools used in the discipline.

  3. Learner-centered tools: There are tools that require some programming skills, but that focus on learning to learn, as well as on learning subjects besides programming. Most hypermedia authoring systems and all Logo environments serve as examples. The Logo programming language that was pioneered by Seymour Papert was specifically designed to create a rich learning environment for children.

  Progress in developing more and better applications packages, as well as better human-machine interfaces, is causing the tool use of computers to grow rapidly. Also, computer scientists working in the field of Artificial Intelligence (AI) are producing application packages that can solve a variety of difficult problems that require a substantial amount of human knowledge and skill. Such application packages will eventually change the content of a variety of school subjects.

  The key issue is what students should learn to do mentally, versus what they should learn to do assisted by simple aids such as books, pencil, and paper, versus what they should learn to do assisted by more sophisticated aids such as calculators, computers, and other information technology. This is a difficult question, particularly given the constantly changing state of technology. The slow acceptance of the handheld calculator into the curriculum suggests that more sophisticated aids to problem solving will encounter substantial resistance. The gap between what tools are available and what tools are used in education is likely to increase.

The computer can also be a tool to increase teacher productivity. Computerized gradebooks, data banks of exam questions, computerized assistance in preparing individualized education plans (IEPs) for students with disabilities, and word-processed lesson plans and class handouts are all good examples. These increase the teachers' productivity by improving overall efficiency of effort and saving valuable time. This is particularly true when networks allow teachers to easily share successful materials.

Many teachers now make use of a desktop presentation system as an aid to interacting with a group or whole class of students. This is a projector system attached to a computer. It can be used to display pre-prepared materials or graphs and other materials that are generated during the interaction among students and the teacher. For example, in a math class, the computer and projection system can be used to create and project a graph of data or a function being generated by the students. In a social studies class, maps can be retrieved from a CD-ROM and projected for whole class viewing.

Computer-Assisted Learning

- Computer-assisted learning (CAL) is the interaction between a student and a computer system designed to help the student learn. During the past 40 years, this general concept has been given many different names, such as computer-based instruction and computer-assisted instruction. The CAL name is intended to emphasize "learning" rather than just "instruction."

Historically, CAL developed along two tracks. Well-funded projects, such as those carried out by the military, produced very sophisticated simulations that were used to train radar operators, airplane pilots, tank crews, and commanders of large battle units. Such CAL materials are cost effective in meeting military training needs.

However, military training needs differ considerably from the needs of students in K-12 schools.

The second track of CAL materials consisted of commercial products and a huge number of small scale projects carried out by individuals. For the most part, these projects developed either drill-and-practice materials or tutorial systems designed to help students. Often the projects focused on basic skills, such as arithmetic and reading.

Over the years, CAL has developed into a viable commercial business. The steadily increasing capabilities of computers have been combined with mass storage devices, such as CD-ROM, to produce sophisticated hypermedia-based instructional materials. Now, there is a rapidly growing home market for such instructional materials. Indeed, software has been developed to help even very young children learn to use the computer and then learn from the computer.

The computer can be used for instructional delivery at every age, in every subject area, and with all types of students. Evidence is mounting that CAL is especially useful in special education and in basic skills instruction. In addition, CAL and distance education can provide students access to courses that are not available in a teacher-delivered mode in their schools.

Students With Special Needs

- The three general instructional uses of computers discussed above are, of course, all applicable to students with special needs. However, two additional points are particularly important. First, many students have physically handicapping conditions that can be addressed by use of computer-based adaptive technologies. The well-known physicist Stephen Hawking, who has Lou Gehrig's disease, has helped the general public to become aware of such computer capabilities. Second, many students with various types of learning difficulties can benefit from computer-as-tool and CAL. Both the tool and the CAL materials may need to be designed to fit the student's special needs.

Computer-based adaptive technologies have proven to be invaluable in meeting the needs of a number of students who face major physical challenges. Consider a student whose physical difficulties prevent the use of a pencil for writing or voice for speaking. With appropriate adaptive facilities, this student may be able to communicate in writing by using special input devices to a computer. The same computer system can provide the student with synthesized voice output. As another example, consider a partially sighted or blind student. This student can "read" ordinary text material via video camera or other scanning device that inputs the text materials into a computer for voice output.

Substantial research has provided a foundation for developing computer-based tools and CAL materials to fit the needs of students with various types of learning difficulties. A simple example is provided by the handheld calculator. Many students have difficulty learning to do mental or paper-and-pencil arithmetic at a reliable level. With appropriate instruction and practice, however, many of these students can learn to make effective use of a handheld calculator. Note that if the student also has physical handicapping conditions, a special handheld calculator may be needed. For example, calculators that produce voice-synthesized output are now relatively inexpensive.

Goals for Information Technology in Education

- This section lists 13 goals for computer technology in education. These goals have emerged and evolved during the past 15 years as microcomputers have come into common use in schools and as the information highway has developed. These goals are divided into four major categories: Functional Technology Literacy; Independent Lifelong Learning; Capacity Building; and Assessment and Evaluation. The quality of a school or school district's instructional use of computers can be judged by how well it is meeting these goals. Additional discussion on the ideas of this section is given in Effective Practice: Computer Technology in Education (Moursund, 1995).

Student Goals-Functional Technology Literacy

- The four goals listed in this section serve to define *functional technology literacy* and provide guidelines to K-12 curriculum developers. Notice the combined emphasis on both basic skills and on higher-order, problem-solving skills.

Goal 1: Information technology literacy, basic level. All students shall be functionally literate in information technology. A basic level of information technology literacy should be achieved by the end of the eighth grade. It consists of a relatively broad-based, interdisciplinary, general knowledge of applications, capabilities, limitations, how they work, and societal implications of computers and other information technology. Here are six specific objectives that underlie this information technology literacy goal.

A. General knowledge. Students shall have oral and reading knowledge of computers and other information technology, and their effects on our society. More specifically, each discipline that students study shall include instruction about how electronic aids to information processing and problem solving are affecting that specific discipline.

B. Procedural thinking. Students shall have knowledge of the concept of effective procedure, representation of procedures, roles of procedures in problem solving, and a broad range of examples of the types of procedures that computers can execute.

C. Generic tools. Students shall have basic skills in use of word processing, database, computer graphics, spreadsheet, and other general purpose, multidisciplinary application packages. This also includes basic skills in using menu-driven hypermedia software to create hypermedia materials as an aid to communicating.

D. Telecommunications. Students shall have basic skills in using telecommunications to communicate with people and to make effective use of computerized databases and other sources of information located both locally (for example, in a school library, a school district library, a local community library) and throughout the world. They shall have the knowledge and skills to make effective use of the Internet and the World Wide Web.

E. Hardware. Students shall have basic knowledge of the electronic and other hardware components and how they function sufficient to "dispel the magic." They shall understand the functionality of hardware sufficient to detect and correct common difficulties, such as various components not being plugged in or not receiving power, various components not being connected, and printer out of paper.

F. Computer input. Students shall have basic skills in use of a variety of computer input devices, including keyboard and mouse, scanner, digital camera, touch screen, and probes used to input scientific data. They shall have introductory knowledge of voice input and pen-based systems.

Goal 2: Information technology literacy, intermediate level. Deeper knowledge of computers and other information technology as they relate to the specific disciplines and topics one studies in senior high school. Some examples:

A. Skill in creating hypermedia documents. This includes the ability to design effective communications in both print and electronic media, as well as experience in desktop publication and desktop presentation.

B. Skill in use of information technology as an aid to problem solving in the various high school disciplines. A student taking advanced math would use computer modeling. A commercial art student would create and manipulate graphics electronically. Industrial arts classes would work with computer-aided design. Science courses would employ microcomputer-based laboratories and computer simulations.

C. Skill in computer-mediated, collaborative, interdisciplinary problem solving. This includes students gaining the types of communication skills (brainstorming, active listening, consensus-building, etc.) needed for working in a problem-solving environment.

Goal 3: Computer-as-tool in curriculum content. The use of computer applications as a general-purpose aid to problem solving using word processor, database, graphics, spreadsheet, and other general purpose application packages shall be integrated throughout the curriculum content. The intent here is that students shall receive specific instruction in each of these tools, probably before completing elementary school. Middle school, junior high school, and high school curriculum shall assume a working knowledge of these tools and shall include specific additional instruction in their use. Throughout secondary school and in all higher education, students shall be expected to make regular use of these tools, and teachers shall structure their curriculum and assignments to take advantage of and to add to student knowledge of computer-as-tool.

Goal 4: Information technology courses. A high school shall provide both of the following "more advanced" tracks of computer-related coursework.

A. Computer-related coursework preparing a student who will seek employment immediately upon leaving school. For example, a high school business curriculum shall prepare students for entry-level employment in a computerized business office. A graphic arts curriculum should prepare students to be productive in use of a wide range of computer-based graphic arts facilities. Increasingly, some of these courses are part of the Tech Prep (Technical Preparation) program of study in a school.

B. Computer science coursework, including problem solving in a computer programming environment, designed to give students a college-preparation type of solid introduction to the discipline of computer science.

Student Goals-Independent Lifelong Learning

- The three goals listed in this section focus on computer technology as an aid to general learning.

  Goal 5: Distance education. Telecommunications and other electronic aids are the foundation for an increasingly sophisticated distance education system. Education shall use distance education, when it is pedagogically and economically sound, to increase student learning and opportunities for student learning.

Note that in many cases distance education may be combined with computer-assisted learning (CAL, see Goal 6) and carried out through the WWW (see Goal 1D), so that there is not a clear dividing line between these two approaches to education. In both cases students are given an increased range of learning opportunities. The education may take place at a time and place that is convenient for the student, rather than being dictated by the traditional course schedule of a school. The choice and level of topics may be more under student control than in our traditional educational system.

Goal 6: Computer-assisted learning (CAL). Education shall use computer-assisted learning when it is pedagogically and economically sound, to increase student learning and to broaden the range of learning opportunities. CAL includes drill and practice, tutorials, simulations, and microworlds. It also includes computer-managed instruction (see Objective C below). These CAL systems may make use of virtual realities technology.

A. All students shall learn both general ideas of how computers can be used as an aid to learning and specific ideas on how CAL can be useful to them. They shall become experienced users of CAL systems. The intent is to focus on learning to learn, being responsible for one's own learning, and being a lifelong learner. Students have their own learning styles, so different types of CAL will fit different students to greater or lesser degrees.

B. In situations in which CAL is a cost-effective and educationally sound aid to student learning or to overall learning opportunities, it will be an integral component of the educational system. For example, CAL can help some students learn certain types of material significantly faster than can conventional instructional techniques. Such students should have the opportunity to use CAL as an aid to learning. In addition, CAL can be used to provide educational opportunities that might not otherwise be available. A school can expand its curriculum by delivering some courses largely via CAL.

C. Computer-managed instruction (CMI) includes record keeping, diagnostic testing, and prescriptive guides as to what to study and in what order. CMI software is useful to both students and teachers. Students should have the opportunity to track their own progress in school and to see the rationale for the work they are doing. CMI can reduce busywork. When CMI is cost-effective and instructionally sound, staff and students shall have this aid.

Goal 7: Students with special needs. Computer-related technology shall be routinely and readily available to students with special needs when research and practice have demonstrated its effectiveness.

A. Computer-based adaptive technologies shall be made available to students who need such technology for communication with other people and/or for communication with a computer.

B. When CAL has demonstrated effectiveness in helping students with particular special learning needs, it shall be made available to the students.

C. All staff who work with students with special needs shall have the knowledge and experience needed to work with these students who are making use of computer-based adaptive technologies, CAL, and computer tools.

Educational System Goals-Capacity Building

- The three goals in this section focus on permanent changes in our educational system that are needed to support achievement of Goals 1-7 listed previously.

Goal 8: Staff development and support. The professional education staff shall have computers to increase their productivity, to make it easier for them to accomplish their duties, and to support their computer-oriented growth. Every school district shall provide for staff development to accomplish Goals 1-7, including time for practice, planning, and peer collaboration. Teacher training institutions shall adequately prepare their teacher education graduates so they can function effectively in a school environment that has Goals 1-7.

This means, for example, that all teachers shall be provided with access to computerized data banks, word processors, presentation graphics software, computerized gradebooks, telecommunications packages, and other application software that teachers have found useful in increasing their productivity and job satisfaction. Computer-based communication is becoming an avenue for teachers to share professional information. Every teacher should have telecommunications and desktop presentation facilities in the classroom. Computer-managed instruction (CMI) can help the teacher by providing diagnostic testing and prescription, access to item data banks, and aids to preparing individual education plans.

Goal 9: Facilities. The school district shall integrate into its ongoing budget adequate resources to provide the hardware, software, curriculum development, curriculum materials, staff development, personnel, and time needed to accomplish the goals listed above.

Goal 10: Long-term commitment. The school district shall institutionalize computers in schools through the establishment of appropriate policies, procedures, and practices. Instructional computing shall be integrated into job descriptions, ongoing budgets, planning, staff development, work assignments, and so on. The school district shall fully accept that "computers are here to stay" as an integral part of an Information Age school system. The community-the entire formal and informal educational system-shall support and work to achieve the goals listed above.

Assessment and Evaluation

- The three goals listed in this section focus on doing strategic planning and on obtaining information about the effectiveness of programs for information technology that are implemented by teachers, schools, and school districts.

Goal 11: Strategic plan. Each school and school district shall have a long-range strategic plan for information technology in education. The plans shall include ongoing formative evaluation and yearly updating.

Goal 12: Student assessment. Authentic and performance-based assessment shall be used to assess student learning of information technology. For example, when students are being taught to communicate and to solve problems in an environment that includes routine use of the computer as a tool, they shall be assessed in the same environment.

Goal 13: Formative, summative, and residual impact evaluation. Implementation plans for information technology shall be evaluated on an ongoing basis, using formative, summative, and residual impact evaluation techniques. Formative evaluation provides information for mid-program corrections. It is conducted as programs are being implemented. Summative evaluation provides information about the results of a program after it has been completed, such as a particular staff development program, a particular program of loaning computers to students for use at home, and so on. Residual impact evaluation looks at programs in retrospect, perhaps a year or more after a program has ended. For example, a year after teachers participated in an inservice program designed to help them learn to use some specific pieces of software in their classrooms, are they actually using this software or somewhat similar software?

Goals for Teacher Technology Education

- In recent years, a great deal of thought has gone into determining what computer knowledge and skills teachers need to have. It is clear that a two-pronged approach is needed in teacher education. One prong is aimed at preserve education. Newly graduated teachers must have the knowledge and skills to help our schools achieve the student Goals 1-7 listed in the previous section. The second prong is inservice education. Every school needs to have in place an inservice program that helps all teachers gain the knowledge and skills to achieve the student goals.

  The National Council for Accreditation of Teacher Education (NCATE) is the official body in the United States for accrediting teacher preparation programs. The International Society for Technology in Education (ISTE) has worked with NCATE for a number of years in the development of teacher preparation standards. With assistance from ISTE and others, NCATE has developed technology standards for all preservice teachers. These are called Unit Guidelines. These same goals are a good starting point for inservice education. For both preservice and inservice teachers, the goals listed below are minimal. They provide a starting point, but they are far from the levels of competencies that teachers need if information technology is going to have a significant positive impact on our educational system.

The remainder of this section is quoted from 1996 NCATE materials written by ISTE. This and additional related information can be found on the ISTE WWW site:

http://www.iste.org

All candidates seeking initial endorsements in teacher preparation programs and particularly programs in educational computing and technology require foundations in: 1) Basic Technology Operations and Concepts; 2) Professional and Personal Use of Technology; and 3) Application of Technology in Instruction.

1. Basic Technology Operations and Concepts. Candidates will use computer operating systems and user interfaces to run programs; access, generate and manipulate data; and to publish results. They will also evaluate performance of hardware and software components of computer systems and apply basic troubleshooting strategies as needed.

   Performance Indicators. Candidates will:

   - 1.1 operate a multimedia computer system with related peripheral devices to successfully install and use a variety of software packages.

   1.2 use terminology related to computers and technology appropriately in written and oral communications.

   1.3 describe and implement basic troubleshooting techniques related to using a multimedia system with related peripheral devices.

1.4 operate and interface peripheral devices with a computer system supporting imaging including scanner, digital camera, and/or video camera.

1.5 observe demonstrations or uses of specific-purpose electronic devices and adaptive assistive devices for special needs.

1.6 observe demonstrations or uses of broadcast instruction, audio/video conferencing, and other distant learning applications.

1.7 demonstrate knowledge of uses of computers and technology in business, industry, and society.

2. Personal and Professional Use of Technology. Candidates will apply tools for enhancing their own professional growth and productivity. They will use technology in communicating, collaborating, conducting research, and solving problems. In addition, they will plan and participate in activities that encourage lifelong learning and will promote equitable, ethical, and legal use of computer/technology resources.

Performance Indicators. Candidates will:

- 2.1 use productivity tools for word processing, database management, and spreadsheet applications.

2.2 apply productivity tools for creating basic multimedia presentations.

2.3 use computer-based technologies including telecommunications to access information and enhance personal and professional productivity.

2.4 use computers to support problem solving, data collection, information management, communications, presentations, and decision making.

2.5 demonstrate knowledge of equity, ethics, legal, and human issues concerning use of computers and technology.

2.6 identify computer and related technology resources for facilitating lifelong learning and emerging roles of the learner and the educator.

3. Application of Technology in Instruction. Candidates will apply computers and related technologies to support instruction in their grade level and subject areas. They must plan and deliver instructional units that integrate a variety of software, applications, and learning tools. Lessons developed must reflect effective grouping and assessment strategies for diverse populations.

   Performance Indicators. Candidates will:

- 3.1 explore, evaluate, and use computer/technology resources including applications, tools, educational software and associated documentation.

3.2 describe current instructional principles, research, and appropriate assessment practices as related to the use of computers and technology resources.

3.3 design, deliver, and assess student learning activities that integrate computers/technology for a variety of student grouping strategies and for diverse student populations.

3.4 design student learning activities that foster equitable, ethical, and legal use of technology by students.

3.5 practice responsible, ethical and legal use of technology, information, and software resources.

Evaluating Current Progress

- The educational system in the United States is highly decentralized. There can be major differences in the quality of education that students are receiving in two schools that are in the same school district, to say nothing of the differences that exist between school districts. In addition, there are a large number of private schools in this country.

  Very few schools are currently achieving all of the information technology Goals 1-13 listed in this chapter. Relatively few colleges of education are achieving the NCATE-recommended teacher preparation goals, and there are relatively few schools in which all of the teachers have achieved these goals.

  In summary, we have a long way to go. Each school and school district can assess its current progress against the goals listed in this chapter. This can provide a starting point for developing plans to meet and exceed these goals.

Conclusions and Recommendation

- This chapter covers a number of potential uses of information technology in education. It also contains a list of goals for this field. As with other educational goals, these can be considered to be forecasts. While some school districts are making good progress on achieving these goals, overall nationwide progress has been modest. However, leaders in the field of information technology in education are committed to their achievement. Thus, these goals are already shaping the future. As more and more educators work to achieve these goals, these goals will increasingly shape the future of education.

  Think about what it will mean as distance education and computer-assisted learning become routine parts of our educational system. Each provides learning opportunities at a time and place to better fit the convenience of the learner. Each provides access to a far broader range of courses than even the largest school can make available. Students will be empowered by steadily increasing choice of curriculum content, mode of instructional delivery, time, and place. The current educational system will face steadily increasing competition from distance education and CAL.

A modest number of parents and educators can take the lead in having a school or school district assess its progress in achieving the goals listed in this chapter. Be aware that education is a political "game." It is very helpful to get the media involved. Our educational system can be a lot better. A few parents, educators, and media people working together can produce a significant change in a local education system.

The next chapter explores some of the key characteristics of the Information Age that need to be addressed by our educational system.

<<< Chapter 3 Contents Chapter 5 >>>

Return to Cover Page

<<< Chapter 4 Contents Chapter 6 >>>

Chapter 5

The Information Age-What is it?

- In the United States, the Information Age "officially" began in 1956 when the number of so-called white collar jobs first exceeded the number of blue collar jobs. This chapter introduces the key ideas that help unify the book and serve as a foundation for many of the forecasts. In brief summary:

1. Science and technology during the Industrial Age focused mainly on the understanding of matter at the atomic level. Progress led to the development of an infrastructure and a society that dealt with the manufacturing and distribution of physical goods such as cars, electric motors, refrigerators, and books consisting of ink on paper.

2. Science and technology during the Information Age includes a major focus on information represented as bits (binary digits). The developing infrastructure includes information highways and superhighways, computers to store and process information, and the field of Computer and Information Science (which includes the field of Artificial Intelligence).

Four "Ages"

- Human history is sometimes broken into four major time periods or "ages:"

1. Hunter-gatherer Age. All of human history, up to about 10,000 years ago.
2. Agricultural Age. Helped to ensure larger and more stable food supplies.
3. Industrial Age. Began about 200 years ago; based on engines and their fuels.
4. Information Age. Began about 40 years ago; based on computers and connectivity.

Until about 10,000 years ago, all people on earth could be classified as hunter-gatherers. Education during the hunter-gatherer age was informal-learn by imitating adults, and learn by doing. Schools and the formal education system that we now take for granted did not exist.

About 10,000 years ago, people began to raise crops and to domesticate farm animals. The ability to store and accumulate food produced major societal changes. After about 5,000 years, cities began to emerge, and reading, writing, and arithmetic were invented. Learning the "three R's" required quite a long period of formal instruction and practice. Thus, formal educational systems were developed. In many ways, the classrooms of 5,000 years ago looked quite a bit like the classrooms of today (Logan, 1995).

Of course, for many thousands of years reading materials were scarce and only a few people received the instruction and practice needed to become proficient at reading and writing. Even then, however, reading and writing contributed greatly to an accumulation of human knowledge. This accumulation was slow, because transportation was slow and the electronic communication systems that we now take for granted did not exist.

The Agricultural Age was still continuing when Johannes Gutenberg invented a printing press that made use of moveable type about 550 years ago. This invention made possible the mass production of books. It led to more widespread formal education and the societal changes that accompany having a better educated population.

The Industrial Age began in Great Britain in the late 1700s, not much more than 200 years ago. The invention of the steam engine made possible the augmentation of human power for manufacturing and transportation.

Steam Power

- *It is estimated that the power of steam in Great Britain is equal to the labor of 170,000,000 men, in a population of only 28,000,000.*

Scientific American. (1845, October).

The quote indicated that little more than 50 years into the Industrial Revolution in Great Britain, the installed base of steam power was equivalent (in terms of pure physical power) to about six times the physical power of the entire population of Great Britain. A somewhat different way of representing this information is that the total steam power amounted to a little more than one horse power per person. (One horsepower is about the same as five or six "personpower." Think about that the next time you push down the gas pedal on the 100 horsepower gasoline engine in a car!)

By 1845, Great Britain was the industrial powerhouse of the world. Of course, not every person in Great Britain was working in a factory that made use of steam power. We can speculate that perhaps the average worker in such a steam-powered factory was making use of steam power equivalent to the physical power of a hundred strong people. It was this factor of 100 change that led Great Britain to its world dominance in industrial manufacturing.

The Spread of the Industrial Revolution

- *Britain did not long remain the only country to experience an Industrial Revolution. Attempts to specify dates for the Industrial Revolution in other countries are controversial and not particularly rewarding. Nonetheless, scholars generally agree that the Industrial Revolution occurred in France, Belgium, Germany, and the United States about the middle of the 19th century; in Sweden and Japan toward the end of the century; in Russia and Canada just after the turn of the 20th century; and in parts of Latin America, the Middle East, Central and southern Asia, and Africa about or after the middle of the 20th century.*

(*Microsoft Encarta*, 1994)

It is important to make two points. First, the developments in science and technology that led to the Industrial Revolution gradually spread to the whole world. Second, the steam engine that fostered the beginnings of the Industrial Age was actually only the tip of the iceberg. For example, electricity, vacuum tubes, the internal combustion engine, and the jet engine were still to come. These facilitated such devices as the telegraph, telephone, electric motors, electric lights, automobile, airplane, radio, and television.

World Wars I and II helped to transform the United States into an industrial nation. By the end of World War II in 1945, the United States was the world's leading industrial nation. The huge pent up demand for industrial goods fueled still more growth of industrial manufacturing. In the years after the war ended, well over half of all workers in the country had jobs that were classified as industrial/ manufacturing.

Interestingly, most of these jobs required relatively little formal education. The assembly line jobs were designed to require about a fourth grade education. The "thinking" and decision making was done by a hierarchy of management-level people who had a much higher level of education. A top-down form of management was used.

This pinpoints one of the weaknesses in our current educational system. It was designed for an Industrial Age society, and it uses a top-down form of management and curriculum development. The front line workers being managed-the teachers and teaching assistants-are now highly educated. Many have as much formal education as their managers.

Continued progress in science and technology during the Industrial Age laid the groundwork for the development of an electronics industry, the invention of the electronic digital computer, and the eventual transformation of the United States into the world's first Information Age society.

Mind Tools

- Humans have developed a marvelous range of tools-aids to their physical bodies and to their minds. It is people plus their tools that make possible reading, writing, arithmetic, communications satellites, and artificially intelligent computer systems. It is people plus their tools that fuel the steady march of science and technology.

The transition from the Hunter-gatherer Age to the Agricultural Age made use of considerable insight into nature, along with some simple tools. This was a long and slow process. Even after the development of reading and writing, the worldwide pace of change remained very slow.

The Industrial Age came about through steadily increasing insight into science and technology, along with the development of more sophisticated tools to aid the human body.

The Information Age is based on a rapid pace of progress in science and technology, supported by steady improvements in computer-related technology. We can think of such technology as aids to the human mind, or mind tools. It is these mind tools that are now changing our world.

Development of the Computer

- The early history of computers is one of researchers and inventors working to develop faster and more automatic aids to doing arithmetic computations. Mechanical calculators have existed for hundreds of years. When driven by an electric motor, such a calculator required several seconds to complete a multidigit multiplication or division. Of course, that is far faster than can be done using paper and pencil. However, it is slow relative to the computational demands of modern science and engineering.

  Work on the Electronic Numerical Integrator and Computer (ENIAC), began in 1943, and the machine first became operational in early 1946. It is considered to be the world's first fully operational general purpose electronic digital computer. It could do about 350 multiplications or 40 divisions in one second. Moreover, it could store both the numbers being worked on and the results, so that it could do a sequence of computations without anyone having to re-key in numbers. Roughly speaking, this computer was a thousand times as fast as a person using an electric calculator-a factor of 1,000-surely the thing that major changes are made of!

  Nowadays, a medium-priced microcomputer is more than 100,000 times as fast as the ENIAC. This means that it can do arithmetic about as fast as 100 million people working with electric calculators. How can one explain millions of people owning such machines, even carrying portable machines in their briefcases? Who needs to personally own a machine that can do the work of 100 million people working with electric calculators?

  The answer lies in how such computers are used. We have moved beyond the first-order effect levels of computer use. Most computers are not used to do calculator-like arithmetic computations. Rather, they are used in more demanding tasks such as the storage and retrieval of databases of information, in creating and manipulating graphics, in developing spreadsheet models of business problems, as switching circuitry in telecommunications systems, and in processing digital information from scientific instruments.

We are continually developing tasks that challenge the capabilities of the most powerful computer systems. For example, the combination of continued progress in the underlying science of speech recognition and in building faster microcomputers is just now making possible reasonably priced voice input systems. You can well imagine how voice input will affect the teaching of reading and writing.

Progress is occurring on the computer translation of spoken natural languages. This is an extremely difficult problem. Some futurists feel that the problem will be solved within 15-20 years. How will it affect education and the societies of the world if such automatic translation systems become readily available?

A virtual reality can be considered as a type of simulation. Continuing progress in the hardware and software used for virtual realities is producing simulations of ever increasing quality. Learn about Mars by taking a walk on the surface of Mars, with scientific instruments in hand. Learn about the Antarctic or the deepest parts of our oceans by taking simulated trips into these environments. High quality virtual reality systems demand computing power beyond the fastest of today's microcomputers.

The Age of Bits

- Nicholas Negroponte (1995) talks about the industrial age as being a time in which we developed great skill in manufacturing and transporting physical goods made from atoms. For example, a book is ink printed on paper. We have a huge infrastructure that grows and harvests trees, produces paper, prints the ink onto the paper, and distributes the books. A companion infrastructure assembles the ingredients used to make ink, produces ink, and distributes it to places where it is used, such as to printing plants. The paper and ink are made of atoms-they are physical entities. A significant part of the cost of a book is the cost of shipping and warehousing its atoms. Moreover, economies of mass production at the printing press dictate that a relatively large number of copies be printed at one time-often this turns out to be far more than can be readily sold. Since the cost of warehousing is relatively high, books go out-of-print and new copies are no longer available.

Contrast this with an electronic book, perhaps stored on a magnetic or laser disk. Although the storage medium consists of atoms, the book itself can easily be copied and copies can be cheaply transmitted to other locations at nearly the speed of light. There is no warehousing problem, transportation costs are minimal, and there is no need to print a large number of copies in advance, in the hopes that they will eventually be sold. The book never goes out-of-print.

The representation of information as bits is a revolutionary idea. It is more than just storing, making copies, and transmitting the bits. We can also use the bits to direct the operations of machines such as automated factory equipment, data gathering devices, and robots. Bits can be stored in a form to facilitate interaction with people who want to make use of the bits, such as in an interactive encyclopedia or in computer-assisted learning.

The representation of information as bits, and the aids that computers provide in the storage, manipulation, and transportation of bits, bring new dimensions to human intellectual endeavor. As we come to better understand the potentials of these new dimensions, we can come to understand needed changes in our educational system.

Many people consider Nicholas Negroponte to be an astute visionary. Part of his vision of the future is captured in the following quote. It forecasts continued rapid progress in information technology, communications technology, and Artificial Intelligence.

- *Early in the next millennium your right and left cuff links or ear rings may communicate with each other by low-orbiting satellites and have more computing power than your present PC. Your telephone won't ring indiscriminately; it will receive, sort, and perhaps respond to your incoming calls like a well trained English butler.*

Negroponte. (1995) p. 4.

In brief summary, the combination of computer and communications technology with continued research in all academic areas suggests:

1. More and more of the collected information of the world will be represented as bits. This is less expensive, provides easier and cheaper access, and uses less resources than storing atoms and moving them around.

2. More and more people will have easier and easier access to the information that is stored as bits. The nations of the world are making rapid progress in building information superhighways. Knowledge is a form of wealth, a form of power, and it is of ever growing importance.

3. If a problem can be appropriately represented on a computer and solved by a combination of computing power and people power, increasingly that is the way it will be done. Computers and telecommunications will play a steadily increasing role in solving problems and accomplishing tasks.

Alvin Toffler (1980, 1990) is author of a number of visionary books. His ideas regarding the changes going on in our world are rooted in careful research and thorough analysis. Toffler's 1990 book focuses on how information technology is leading to a shift in who has the power. Knowledge is power. A smart, well-educated, hard working person can acquire a great deal of knowledge (power). Moreover, formal education credentials are not the only measure of the person's education. "Street smarts"-practical, down to earth, knowing how to get things done-is increasingly important.

Person Plus

- Human ingenuity, computers, and communications-together they are a powerful combination for solving problems and accomplishing tasks. People have long used tools to supplement their physical and mental powers. In recent years, perhaps due to the growing importance of mind tools, the idea of *Person Plus* has been developed (Perkins, 1992). The basic concept in Person Plus is that it is people plus tools that solve problems and accomplish tasks. Thus, education should include a major focus on preparing students to work in this Person Plus environment. Both instruction and assessment should be done in environments in which mind tools such as computers and telecommunications systems are readily available.

Figure 5.1 illustrates key concepts of Person Plus as they relate to the Information Age. These concepts are explained in subsequent paragraphs.

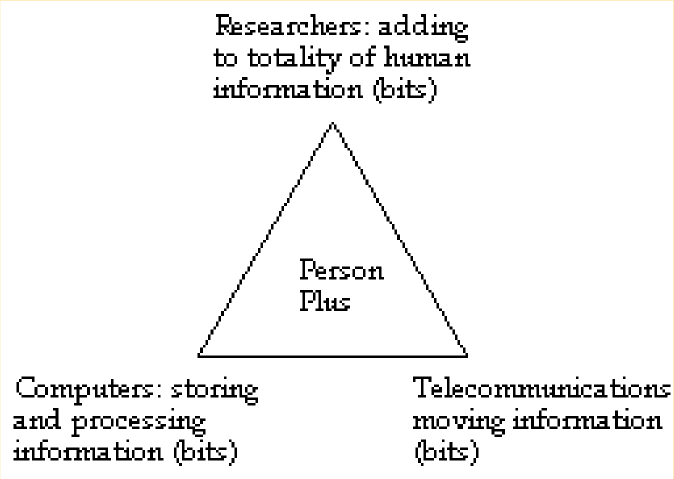

Figure 5.1. Person Plus in the Information Age.

Figure 5.1 shows Person Plus at the center of a triangle of three rapidly changing components:

1. The totality of human knowledge and information is steadily growing. Researchers throughout the world are aided by the steady growth of knowledge and information, improving telecommunication and transportation systems, and improving tools such as computers to aid them in their research.

2. Fiber optics, communications satellites, and cellular telephones are the basis for very rapid growth in the world's telecommunications system. It is becoming steadily easier for people to collaborate on projects and to share information.

3. The capabilities of computers are growing steadily, and the worldwide installed base of computers is growing rapidly. This growth in computer

capabilities comes from progress in both hardware and software. Significant effort in research and development by the world's researchers is going into developing computer tools that they (and others) can use-both to aid in research and to aid in making use of the research results.

The net result is that the capabilities of Person Plus are growing quite rapidly in many different problem-solving areas. People who are skilled at functioning well in a Person Plus environment have a distinct advantage over those who lack the knowledge, skills, and access to the facilities. Such analysis leads to the prediction that Person Plus will become a central theme in education.

Conclusions and Recommendation

- The transition from an Industrial Age to an Information Age can be viewed as a transition from an emphasis on the manufacturing and distribution of physical goods (made from atoms) to the manufacturing and distribution of bits. Of course, the goods and services of agriculture and industry are still needed. However, bits are of rapidly growing importance.

  The transition from an Industrial Age to an Information Age can also be viewed as a transition from an emphasis on Industrial Age mind tools (the three R's, paper and pencil, printed books) to Information Age mind tools (information technology).

  Person Plus is a shorthand phrase for a person building on the collected knowledge, skills, and wisdom of other people. One of the unforeseen second-order effects of information technology is that it would prove to give such a powerful boost to Person Plus. This boost, all by itself, is more than enough justification for a major restructuring of our school curriculum.

  In recent years we have been seeing a steady increase in the amount of computer and telecommunications technology being used in our educational system. This is opening a window for innovations, competition, and major change in our educational system. Many of the current components of our formal educational system will be hard pressed to meet the challenge, implement appropriate innovations, and survive the changes that are inevitable.

  The next chapter includes some forecasts about the information technology industries. It lays groundwork for forecasts about technology in education.

<<< Chapter 5 Contents Chapter 7 >>>

Chapter 6
The Information Technology Industry

- This chapter takes a look at the information technology industry. Progress in the science and technology of computers and telecommunications is being driven by business, government, military, entertainment, and the home market. This is a worldwide phenomenon that has huge momentum. In recent years, the pace of change has been increasing-and this is built on huge changes that have already occurred.

Digitization

- The previous chapter included a section discussing Nicholas Negroponte, one of the world's leading visionaries for electronic technologies. His 1995 book, *Being Digital*, explores how the world will change as more and more information is digitized (represented using 0s and 1s) and as the power of the information processing and telecommunication systems continues to grow. A number of his predictions discuss major changes that will occur in the way that business is conducted. We are already beginning to see this, as the Web emerges as a powerful aid to business.

  The following brief news item presents one obvious advantage of digitized information. When digital information is being sold, delivery can be both inexpensive and fast. There is no use of a transportation system or delivery people.

Egghead Moves Software Sales to the Internet

- *Egghead Inc. has become the first major software retailer to deliver its computer programs directly to the customer via the Internet. A number of Internet sites sell software online, but the product is then boxed up and shipped to the buyer by mail. Egghead's move is the first of several pilot projects backed by Microsoft to bolster the ability of traditional retailers to compete with software companies that distribute their products directly via the Net. Analysts predict that online distribution will account for 20% of retail software sales by the end of next year.*

Wall Street Journal. (1996, November 8). p. B6.

All print materials can be digitized. All film, audio tapes, and video tapes can be digitized. All photographs can be digitized. A substantial amount of "how to" information-for example, how to use a machine tool to manufacture a particular part, or how to solve a particular type of math or science problem-can be digitized.

The digitization of books, videos, and other static information produces second-order effects. A digitized book can be shipped across the country faster than a hard copy of the book. It does not go out-of-print because of the economics of printing presses. Progress in Artificial Intelligence has produced systems that can read digitized text out loud. Thus, a sight-impaired person can now gain access to any textual materials that have been digitized.

For still another example of a second-order effect, consider the "how to" books. The computerization of "how to" information adds a new dimension to a book. A computerized machine tool can store instructions for how to make a particular item, and it can make it. A computerized mathematics package can store information about how to solve various types of math problems, and it can solve the problems. A computer-driven laboratory instrument can both gather and analyze data-and then make changes to what information is being gathered and how it is being processed, in order to better accomplish its assigned task.

The trend toward digitization can be considered to be a megatrend (see Appendix). It is now in full swing, and it certainly will continue. As the next section in this chapter suggest, we are only at the beginning of this digitization megatrend.

Ubiquitous Computing

- Researchers at the Palo Alto Research Center of Xerox Corporation are working on a variety of computer/communication systems which will be built into hundreds of different items. This research group envisions well over a hundred such computer/communication devices in a typical room of a typical house. They have coined the phrase ubiquitous computing to refer to this idea (*Scientific American*, 1995, pp. 78-89).

  For example, imagine a small and inexpensive transceiver that stores some digital information, broadcasts it when directed to do so, and can be built into almost anything. It could be built into a name badge or identification card (this is now being done), print books, and your key case and billfold. If you are looking for a particular book in your house, you ask your main computer system to find it. Your computer system broadcasts a message to the book's transceiver. Your computer system uses triangulation information from several receivers placed throughout the house to pinpoint the location of the book. It also receives a brief description of the book's contents and displays it for you.

  Bill Gates, co-founder and currently chairman of Microsoft, Inc., has received a lot of publicity for the $50 million house he is having built. One of the features of this house is that visitors will receive a transceiver name badge that contains information abut their personal interests in music and art. As a visitor enters a room, the sound system and television system will play music and display artwork aligned with the visitor's interests.

  The Xerox PARC researchers are studying three different categories of computer/communication devices that will likely be part of ubiquitous computing: tabs, pads, and boards. Tabs are small-they can easily be built into a name badge or the spine of a book. Pads are roughly the size of a pad of notebook paper. They are used for writing and displaying notes-as scratch pads, and for doodling. Boards are large-like a white board or blackboard, for interaction with a roomful of people.

  Many other companies are working on products that will contribute to ubiquitous computing. The "smartcard" provides a good example of major changes we can expect as ubiquitous computing occurs. A credit card-sized computer can contain a microprocessor, memory, and programs.

Motorola-Getting Smarter All the Time

- *Motorola is planning to increase its smartcard production capacity ten-fold over the next few years: "Motorola will have the capacity to produce 10 million smartcard microchips per week by the year 2000," says the company's smartcard operations manager. The cards increasingly will be used for such things as social security payments, driver's licenses, passports and credit-card-type transactions. "A significant portion" of Motorola's $2.5 billion investment in semiconductor facilities this year is going toward smartcard production.*

Investor's Business Daily. (1995, October 25). p. A17.

Smartcards at the 1996 Olympics

- *In Atlanta, BellSouth says that prior to this year's Summer Olympics it will install 200 phones that accept "smartcards" that store monetary values from which the cost of telephone calls can be automatically deducted. Someday soon, consumers will be able to use the phones like an automated teller machine-withdrawing money from a bank or credit card account and storing it on a smartcard.*

Atlanta Journal-Constitution. (1996, February 20). p. E1

The first news item indicated that Motorola is betting big on the future of the smartcard. Many other companies are doing likewise. Note that Motorola's planned level of productivity-about 520 million smartcards a year-is roughly equivalent to one smartcard for each ten people on earth.

The second news item indicates that a telephone can be modified to provide connectivity between a smartcard and the computer systems of the world. It will become commonplace for people to carry smartcards and other very small computers, and to make routine use of them.

A Media Merger

- The fields of telecommunications, electronic entertainment (including television and interactive games), and computers are rapidly coming together. We see this in business mergers and we see it in products that are coming to market.

Papers Move Online

- *The number of North American papers available through online services nearly tripled last year to about 175, and is expected to double again this year. About 600 other newspapers published outside North American are also available online, according to the Newspaper Association of America.*

Toronto Sun. (1996, February 14). p. 35.

Note that although the number of online newspapers is a very small percentage of all newspapers, we are likely witnessing the start of a major trend. Notice also that this is happening in many countries-not just in the United States.

A similar trend is occurring for magazines and for research journals. Each publisher is faced by what to publish in hard copy, what to publish on CD-ROMs or DVD-ROMs, and what to publish electronically. It is clear that hard copy will not disappear overnight. However, we are seeing rapid growth in online publications. This is now a megatrend, and continued rapid growth in online publication can be expected.

Compaq, Thomson to Build PC-TV

- *Compaq Computer and Thomson Consumer Electronics are teaming up to produce devices that combine the functions of PCs and televisions, and plan to have their* *first products out in a year or so. Compaq is the biggest PC seller, and Thomson is the largest U.S. maker of TV sets. "What we have is two big companies smelling a market and trying to figure out how to reach it," says the president of a New York technology research firm. "Digital electronics is moving very rapidly into the consumer space and it's very clear there will be TV-PCs or PC-TVs in many forms. What's less clear is who will sell them and where will they go in the house. There's a lot of market research to be done."*

Investor's Business Daily.

(1996, May 23). p. A3.

Net Effect

- *A study by the Cambridge (U.K.)-based consulting group Analysys says that the Net is a disruptive technology that will force the convergence of telecommunications, information technology, publishing and broadcasting, and that it has "usurped elegantly engineered plans for expensive networks put forward by the telecoms operators to become the focus of development and innovation for advanced services." The study characterizes the Net as a miniature model of the communications industry in the next century.*

Financial Times. (1996, March 5). p. 11.

Will Computers Replace TVs?

- *MIT Media Center Director Nicholas Negroponte says he's decided computers are going to replace TVs because "for the past five years, people who build TV sets have been putting more and more computation into their TVs, and people who build personal computers have been putting more and more video into their personal computers. When these two industrial trends converge, there will be no distinction between the two ❱ In the future, we won't be pushing bits at people like we're doing today. It doesn't matter whether you call the receiver a TV or a PC. What's going to change is how those bits are delivered."*

Wired. (1995, November). p. 146.

Growth of the Electronics Industry

- The electronics industry is now quite large and it is continuing to grow quite rapidly.

Silicon Famine

- *Analysts at Dataquest and Rose Associates are predicting a shortage of silicon wafers used to manufacture microprocessing chips that will hamper chip makers' ability to meet demands for the next few years. According to Dataquest estimates, the silicon drought could last into the next century, at least for the 200-millimeter size wafer. The problem arises from the non-stop demand since 1990-historically up until then, demand had slackened every three years or so, giving silicon suppliers a chance to catch up. But with chip output rising to record levels over the past few years, "the whole food chain is stretched right to a thin hair," says the president of Rose Associates.*

Business Week. (1996, March 25). p. 82.

The following two brief news items appeared earlier in this book. They suggest that the impending silicone shortage will be overcome and that continued rapid growth will occur in the electronics industry.

Chip Sales Up 40%

- *Revenue from sales of semiconductors rose 40% last year, to $154.7 billion, according to preliminary results compiled for a new study by Dataquest. North American chip makers' lead over Japanese competitors narrowed to 0.3%, down from 1.2% last year-with North American suppliers claiming 39.8% of the market to Japan's 39.5%. Dataquest predicts healthy sales in the future, fueled by global* *demand for PCs and corporate networks, and estimates chip sales will top $300 billion by the year 2000.*

Wall Street Journal. (1996, January 9). p. B2.

Growth in the Electronics Industry

- *Vladi Catto, chief economist at Texas Instruments Inc., says the industry might expand by 20% a year for the next two decades. By comparison, since TI made the world's first microchip 36 years ago, the industry has averaged 15% annual gains.*

Business Week. (1996, January 8). p. 95.

The first of the previous two news items contains baseline data-where we are now. The second is a forecast of yearly growth in the electronics industry at an even higher rate than we have averaged over the past three decades. A 20% annual rate of growth, sustained over a period of years, produces astoundingly large numbers.

The table given in Figure 6.1 projects a more conservative growth rate of 15% a year. This would be a continuation of the yearly growth rate of the past 36 years, and is considerably less than the forecast provided by Vladi Catto. In addition, the table is extended for only 15 years from 1995. Predictions based on continued compound growth rates far into the future are highly suspect. However, they are interesting to look at and speculate about.

Year	Worldwide Sales (Billions of $)	World Population (Billions)	Sales Per Person
1995	$154.70	6.00	$25.78
1996	$177.90	6.09	$29.21
1997	$204.59	6.18	$33.10
1998	$235.28	6.27	$37.50
1999	$270.57	6.37	$42.49
2000	$311.16	6.46	$48.14
2001	$357.83	6.56	$54.54
2002	$411.51	6.66	$61.80
2003	$473.23	6.76	$70.02
2004	$544.22	6.86	$79.33
2005	$625.85	6.96	$89.88
2006	$719.72	7.07	$101.83
2007	$827.68	7.17	$115.38
2008	$951.84	7.28	$130.72
2009	$1094.61	7.39	$148.11
2010	$1258.80	7.50	$167.81

Figure 6.1. Projected growth of the semiconductor industry.

In Figure 6.1 we have started with the 1995 baseline data. In the second column, we have then projected a 15% a year annual growth for the next 15 years. The third column is a rough estimate of the world's population, with an estimated 1.5% annual rate of growth. The fourth column is an estimate of yearly dollars of production of semiconductors per person on earth.

All of the dollar amounts in Figure 6.1 are in 1995 dollars. Thus, the $167.81 per person amount in the year 2010 is roughly a tenth of the cost of a medium-priced microcomputer. However, a medium-priced microcomputer in the year 2010 will be at least 100 times as fast as the 1995 microcomputer. The net effect is that the amount of computing power being produced in the year 2010 will likely be the equivalent of 10 medium-priced vintage 1995 microcomputers-for every person on earth!

The Telecommunications Industry

- The telecommunications industry makes use of two basic modes of delivering bits of information: land lines, and electronic broadcasts. Examples of land lines include the "twisted pair" copper wires that come into many homes, coaxial cables, and fiber optics. Examples of electronic broadcasts include cellular telephones, microwave transmission systems, and earth-orbiting satellites. The two basic modes of delivering bits of information are often combined in a communications system.

AT&T Unveils Wireless Link to Long-Distance Network

- *AT&T has developed what it calls the "communications medium for the 21st century"-a wireless system that bypasses the local phone network to link residential and business phones directly to the company's long-distance network. The system, which operates via a small transceiver attached to the side of a house or building, provides at least two phone lines and data transmission at twice the speed available over Bell company lines. "When we call this a breakthrough, we're placing it in the same category as satellite and fiber-optic transmission and electronic switching," says AT&T President John Walter. The company claims its new system, nicknamed Project Angel during the development phase, will beat regular wired service in call quality and error-free data transmission.*

Wall Street Journal. (1997, February 26).

One way to think about the two general categories of connectivity is that the amount of broadcast capacity is relatively limited while the amount of land line capacity is essentially unlimited. The physics of broadcasting-there are a limited number of frequencies-provides bounds to growth in broadcast capacity. However, more and more fiber optics can be produced and installed, and still use up only a small part of the physical space available on earth.

To put this into perspective, we are used to the idea of individual telephone lines being readily available at home and work. You can pick up a telephone and direct dial to well over a billion telephones located throughout the world. Although the quality of the connection varies, chances are that the connection will be good enough to carry on a conversation or to transmit electronic bits of information at perhaps 14,400 or 28,800 bits per second or more. Thus, you can send fax or e-mail messages.

The bandwidth of this "telephone conversation" level of connectivity is adequate for some tasks, but totally inadequate for others. For example, a computer screen size color photograph that is digitized and stored in a computer might require about 5 million bits of storage. To transmit this picture on a 28,800 bits per second line would take about three minutes. A video consisting of 24 frames per second would require more than an hour of such transmission for each second of full-motion video.

This problem has been approached in two distinct ways. First, it is possible to "compress" a digitized picture into a greatly reduced number of bits. Using sophisticated mathematical techniques, it is possible to achieve a compression ratio of about 100 to 1. This means that the picture can be sent 100 times as fast, provided one has appropriate software and computing power at the sending and receiving stations. (With a 100 to 1 compression ratio, one hour of video is approximately 5 gigabits-that is, 5,000,000,000 bits.)

Second, tremendous progress has occurred in making better use of the "twisted pair" of copper wires used in telephone systems. The following brief news item summarizes the progress.

Speedy Modems

- *The new HotWire system from Paradyne Corp. uses an RADSL (rate adaptive digital subscriber line) modem that can send data at speeds up to 2 million bits per second, making it possible to send video over ordinary telephone lines. The technology is more than 15 times faster than conventional ISDN (integrated services digital network) lines.*

Tampa Tribune. (1996, September 21). pp. B&F1.

The combination of data compression and the new type of modem mentioned above means that pictures can be sent over ordinary telephone lines perhaps 5,000-10,000 times as fast as is suggested by our first calculations. This is fast enough to send television-quality video in real time over an ordinary telephone line.

A second approach to providing high bandwidth connectivity to people's homes is to use the cable television system. (Note that the "hundreds of times faster than ordinary telephone lines" speed mentioned in the following news item is a comparison with a 28,800 bits per second modem-not the much faster modem analyzed above. Clearly, there is an interesting competition shaping up between the cable industry and the telephone industry.)

Motorola's Million Cable Modems

- *Motorola is shipping the first of a million cable modems ordered by cable companies such as Time Warner, TCI and Comcast, among others. Cable operators plan to charge between $25 and $40 a month for online access at speeds hundreds of times faster than ordinary phone lines. Critics have cited problems with cable modem technology, including electrical "noise," limitations on two-way transmissions, and potential user overload, but a Motorola VP says, "Bullfeathers, this stuff works and it's in homes."*

Wall Street Journal. (1996, April 29). p. B7.

Australian Cable Company Has It All

- *Optus Vision, the partly owned cable subsidiary of Australia's No. 2 long-distance company, is now able to offer television, telephone and high-speed data services through a single network-long the goal of the U.S. cable industry. "The U.S. has taken longer than everybody thought," says a Motorola general manager, who notes that U.S. cable operators have delayed their all-in-one systems because of the daunting task of upgrading older plants and equipment to provide telephony and two-way data links. Optus was able to build its network from scratch.*

Wall Street Journal. (1996, June 28). p. B4.

A third approach to high bandwidth connectivity into homes and other places is use of fiber optics. Fiber is now cheap enough so that many new homes are built with fiber connectivity rather than the traditional twisted pair of copper wires. Currently available fiber optics have more than a thousand times the bandwidth of the twisted pair of copper wires used by the telephone companies. Moreover, this technology is also making rapid progress.

A Trillion Bits Per Second

- *Three separate groups of researchers have succeeded for the first time in transmitting information at a rate of one trillion bits per second-a terabit-through an optical cable. Fujitsu, Nippon Telephone and Telegraph, and a team from AT&T Research and Lucent Technologies reached the terabit threshold four years earlier than expected.*

Communications of the ACM. (1996, May). p. 11.

A speed of one trillion bits per second is 400 times the speed of the fastest commercial optical fiber systems currently in use. Using the types of data compression ratios that are often used to store and transmit video, such a speed means that two hours of video could be transmitted in 1/25 of a second over a single fiber. A typical fiber optic "cable" contains from a dozen to several hundred fibers.

A fourth approach to high bandwidth connectivity into homes and other places is use of satellites and earth-based digital broadcast systems. The next decade will bring us the satellite system discussed in the following brief news item.

Motorola's M-Star Reaches for the Sky

- *Motorola has a new $6.1-billion satellite project on the drawing board, comprising 72 low-orbit satellites capable of transmitting voice, video and data worldwide. The M-Star project is separate from Motorola's Iridium project, in which it's a 30% owner. M-Star is expected to take four years to complete from the time it receives FCC approval and lines up investors. The network will offer speeds of up to one gigabit for satellite-to-satellite laser communications and 155 megabits for satellite-*

to-earth transmissions.

Wall Street Journal. (1996, October 14). p. B4.

Teledesic Gets Approval From FCC

- *Teledesic, the privately owned company owned by Craig McCaw and Bill Gates, has won FCC approval to proceed with its plans to launch an 840-satellite computer network. In 1990, Teledesic's plan was to use an orbiting grid of satellites to send data around the world, but the current plan is to provide high-speed computer access by transmitting from a rooftop antenna to the satellites in orbit. The Boeing Corporation could play a big part in building or launching the satellites, and other companies are also likely to help underwrite the $9-billion project.*

Seattle Times. (1997, March 15).

On a worldwide basis, there are a number of companies in the process of developing orbiting satellite systems. In early 1997 there were about 150 commercial satellites in orbit. Plans had been developed for orbiting an additional 1,700 such satellites during the next decade. These will serve a variety of communications purposes. One goal is to make possible portable telephone and Internet service from every place on earth via satellites.

Hardware Technology Specifics

- It is relatively easy to predict a number of characteristics of the computer hardware that will be commercially available about 5 years from now. That is because it takes about 5 years to move a chip from pilot production to large scale production. Predictions up to 10 years are reasonably good if done by those who have intimate knowledge of the leading edge research frontiers. That is because it takes about 10 years to move from this leading edge research through pilot production and into mass production of the chips.

With this type of background, we can examine quotes such as the following:

Chip Wars Continue

- *Texas Instruments says it will begin manufacturing a chip next year that will be 20 times more powerful than today's Pentium Pro chip from Intel. The new chips will be used in automatic teller machines that can recognize a user's face, wristwatch PCs, or laptop computers with longer memory life. TI's TImeline chip-making process will pack 125-million transistors onto a single chip, beating LSI Logic's prediction that it soon will make a 49-million transistor chip. "What they announced is no different from where every semiconductor company is headed toward," says an industry analyst. "The question is, is there some reason to believe they can do it faster than their competitors?"*

St. Petersburg Times. (1996, June 3). p. 8.

New Process Yields Sturdier, Faster Chips

- *Engineers at the University of Illinois have discovered that a simple substitution in the computer chip manufacturing process could increase chips' lifespan by 10 to 50 times, or alternatively, allow them to operate at faster speeds. By treating a chip with deuterium instead of hydrogen in the final stage of the manufacturing process, the resulting product is better able to weather the battering it takes from the electrons that store and transmit messages. "The tantalizing thing will be to use the trade-off between lifespan and performance to make the chip work even faster," says one researcher, who estimates the substitution process would add only about $1.50 to the cost of a wafer of chips.*

Investor's Business Daily. (1996, February 15) p. A9.

Scalpel Technology Packs More Power on a Chip

- *Bell Labs researchers have come up with a way to use electron beams to imprint microchips, inscribing four times more features onto a chip than today's standards. The electron beam machine, dubbed Scalpel, will enable the chip industry "to continue the success that it's had over the past decades of reducing the size of the chip every couple of years. It looked like with conventional optical lithography techniques that they'd run out of gas sometime around the end of the century," says the head of Bell Labs' advanced lithography research unit. "Electron beams have been around for a long time. But in terms of writing chips on wafers they were slow so nobody used them commercially ⟩ So what we've done with Scalpel is figure out a way to ⟩ make an electron beam printing technique that isn't slow and will have the ability to imprint smaller and smaller features."*

Investor's Business Daily. (1996, August 13). p. A8.

Cookie-Cutter Microchips

- *While other researchers are experimenting with X-ray lithography for etching minute lines onto silicon wafers, a professor at the University of Minnesota has developed a way to stamp ultra thin lines on microchips "almost like they were cookies." Stephen Chou's research team recently was able to imprint wafers with lines just 0.025 microns wide, and Chou's "quite confident" that they can get down to 0.01-micron lines-"maybe even smaller."*

Business Week. (1996, May 6). p. 95.

If the "Cookie-Cutter Microchips" forecast proves to be correct, this will be an astounding breakthrough. Current state-of-the-art chip factories are able to imprint wafers with lines that are 0.25 to 0.35 microns in width. A factor of 10 decrease in line width means a factor of 100 increase in the number of transistors that will fit on a given sized chip.

At the current time, South Korea leads the world in the production of computer memory chips. However, many other companies are competing in this market. One news items talks about a billion bit memory chip, while the other talks about a four billion bit chip. Today's medium-priced microcomputer typically comes with about 16 megabytes of chip memory. One of the gigabit chips has eight times this capacity, and one of the 4-gigabit chips will have 32 times this capacity.

Computer Memory Chips

- *South Korea's Samsung Electronics says it's the first company in the world to develop a prototype circuit design for the 1-gigabit direct random access memory (dram) chip for use in multimedia applications. The new chip will be able to store up to 15 minutes of moving pictures and the equivalent of 8,000 newspaper pages.*

Financial Times. (1995, December 12). p. 1.

Four Gigabit Memory Chip

- *NEC is developing a 4 gigabit memory chip; it will store 47 minutes of full-motion video, or 256 times the capacity of the 16-megabit DRAM chip now commonly used. NEC says it will begin selling the chip around 2000.*

New York Times. (1997, February 7).

There is a huge and rapidly growing worldwide demand for computer memory chips. Samsung and NEC are but two of the many companies that are investing in the research and in the manufacturing capacity needed to meet this steadily growing demand.

Worldwide construction of chip manufacturing plants during the 2-year period 1995-96 was approximately the same as the number of plants constructed in the previous 10 years. As suggested in the following quote, the costs are staggering.

Costs of Chip Factories

- *From about $550,000 25 years ago, the price of a megabyte of semiconductor memory has declined to just about $38 today. But, during the same period, the cost of building a factory to manufacture such memory chips has risen from less to $4 million to a little more than $1.2 billion, putting the business beyond the reach of all but a few very large firms.*

Scientific American. (1996, January). p. 54.

Note that the article containing the above information was written just before a massive decline occurred in the sales price of memory chips. (The price decline has been attributed to an oversupply.) At the time this book was being written, chip memory was selling for less than $10 per megabyte.

Smaller Chips, Bigger Prices

- *As the projected costs skyrocket for sophisticated chip fabs capable of cranking out system-chips equipped with more than 100 million transistors, Intel co-founder Gordon Moore points out that chip making already is the world's "most expensive real estate speculation." Currently, turning wafers into microprocessors costs $1 billion per acre of silicon. The cost for wafer-fabrication plants capable of manufacturing super chips with 0.07-micron transistors could run as high as $10 billion, he warns.*

Business Week. (1996, December 9). p. 148.

IBM to Build Ultrasupercomputer

- *IBM has signed a $94-million contract with the U.S. government to build an ultrasupercomputer-capable of handling 3-trillion operations per second and retaining 2.5-trillion bytes of memory. Energy Secretary Hazel O'Leary calls the DOE Option Blue a "dramatic leapfrog" over existing technologies. Option Blue's main job will be to simulate the performance and deterioration of the nation's stockpile of nuclear weapons, a function that once required actual underground testing. The U.S. is now observing a moratorium on such testing, and will rely on electronic modeling instead. Option Blue is the second machine ordered by the Energy Department for use in simulated weapons testing-Option Red, a smaller machine capable of handling 1.5-trillion operations per second, was ordered from Intel Corp. last year and will be installed at the Department's Sandia National Laboratory in December.*

St. Petersburg Times. (1996, July 27). p. E2.

DOE's Accelerated Strategic Computing Initiative

- *The reduction of the arms race is causing a computer race, as the U.S. Department of Energy steps up the pace of developing high-performance computers. "In this program, we have to work with the computer industry to compress the length of time between ❱ generations of computers," says the DOE deputy assistant secretary for strategic computing and simulation. The high-powered machines are needed to perform the complex calculations that are used to assess factors such as the impact of aging on weapons and their ability to perform. The DOE says it will need supercomputers capable of performing at least 100 trillion operations per second by the year 2004. To accelerate the process, the agency has established the Academic Strategic Alliances Program to create and fund university "centers of excellence."*

Science News. (1997, January 4). p. 7.

It is clear that the worldwide electronics industry is "betting big" on the future of information technology. The electronics industry is sufficiently confident in the forecasts for continued rapid growth that it is willing to invest many billions of dollars each year.

Secondary Storage

- The past few years have seen a very rapid drop in the cost of secondary storage. Many medium-priced microcomputers now come with a gigabyte hard disk drive. In terms of storing pure print materials (no pictures), a gigabyte is approximately 1,000 books. The future will see continued rapid progress in developing ever larger and more cost effective secondary storage devices.

IBM Develops Hefty Hard Drive

- *IBM has developed a computer hard-disk drive capable of storing five billion bits per square inch, or three times as much as the most advanced systems it currently sells. The new drives won't reach the consumer market for several years. IBM expects that it will reach the 10-billion bits per square inch level by the end of the decade.*

New York Times. (1996, December 31). p. C4.

TeraStor Technology Boosts Storage Capacity

- *New technology from TeraStor Corporation could be a major breakthrough for the computer storage industry, say analysts. The company's "near field recording technology" is a hybrid of magnetic storage systems found in most PCs and the laser-based optical storage more common to compact disks. TeraStor's founder predicts that by next year, the new technology will be used to create a disk that holds 20 gigabytes of information on each side, 10 times the capacity of a single disk today.*

Wall Street Journal. (1997, March 3).

Holographic Data Storage

- *Scientists are on the verge of a new dimension in data storage-holography. Companies such as Rockwell, IBM and GTE are expanding their efforts to develop holographic memories that can store hundreds of billions of bytes of data in a crystal about the size of a sugar cube. The devices initially will be used for a handful of specialized applications that require extraordinary capacity and speed, such as fingerprint ID systems. But when the technology matures and becomes less expensive, it could easily show up as a high-capacity digital storage medium for general purpose computing.*

Scientific American. (1995, November). p. 70.

Display Technology

- Computer display technology is continuing to improve. At the current time, the TV-type display still dominates the market. Such cathode ray tube (CRT) technology predates the development of television in the mid-1930s.

HP, Compaq to Invest in Flat Panel Start-Up

- *Hewlett-Packard and Compaq Computer are among 27 investors in a Silicon Valley start-up that plans to manufacture a prototype of a flat-panel display with full-motion color capabilities. Silicon Video's display measures 1/4-inch thick and uses cathode-ray tube technology. The company expects to have the prototype ready within a year.*

Wall Street Journal. (1996, May 14). p. B6.

Flat PC Screens Head for the Desktop

- *Liquid crystal display screens currently cost about five times that of a similarly-sized cathode ray tube screen, but that should be changing over the next couple of* *years, say LCD makers. Next year, major LCD vendors expect to halve the difference, bringing prices down to two-and-a-half times that of CRTs. Analysts say when the difference comes down to that point, the desktop replacement market could really take off. "CRT replacement is inevitable, it's just that in the near term there are a lot of hurdles," says an analyst at Stanford Resources. "The place where it makes the most sense are with large-screen LCDs." NEC recently unveiled a 20-inch high-resolution LCD screen with wide-angle viewing designed as a "CRT-killer" according to a NEC engineer.*

Investor's Business Daily. (1996, May 23). p. A8.

New Display Technology From Xerox

- *Xerox's Palo Alto Research Center has unveiled a new display technology that manages to cram 7 million pixels onto a 13-inch screen using active matrix technology. That's more than three times the number of pixels in today's state-of-the-art displays, and offers 15 to 30 times the resolution available on current laptops. The screens are expensive-$15,000 apiece, say analysts-and Xerox has decided to pursue niche marketing, such as commercial aviation and medicine, in an effort to establish a customer base and get the price down.*

Wall Street Journal. (1996, March 11). p. B6.

A Foldable Computer Display

- *❩ But Asai fears that Japan is now saddled with a tradition-bound university system, a conformist culture, and an attack of complacency❩. What Asai can do to help Japan is focus Hatachi on its most promising technologies. Some of his favorites: light emitting polymers that could form the basis of a home computer display that could be folded and carried as easily as a rubber mat and act as a PC, newspaper, and VCR. Asai would like to see Hitachi take all the work out of using computers by adding voice-recognition software and "intelligent agents" programmed to roam* *the Internet and retrieve information.*

Business Week. (1994, November 18). p. 103.

Software

- As personal computers get both faster and have more memory, there is a steadily increasing amount of computing power available to devote to software. Here are five important software trends:

  - Computer systems will continue to become more "user friendly." A user friendly system is easy to use, easy to learn how to use, and forgiving of mistakes.

  - Continued movement toward seamlessness among various software tools. That is, information is increasingly easily passed between and/or shared among various computer applications. From the point of view of the user, the various computer applications such as word processor, database, spreadsheet, and so on will gradually merge into a single application.

  - Steadily improving agent technology-artificially intelligent "agents" that can help a person to solve problems and accomplish tasks. An agent can sort your e-mail, throwing away pieces (junk mail) that you don't care to even open. An agent can browse the Web, looking for newly published information on topics of your choice.

  - A strong movement toward "learner centered" software. A learner builds on previous knowledge and skills. Learners differ. Software developers are beginning to understand that the human-computer interface must fit the learner's needs. Thus, it must adjust to (accommodate) the various knowledge and skills that different learners bring to the task. We can expect to see significant progress in this in the coming years.

- Object-oriented programming (object-oriented software) will continue to grow in importance. The following quote from Steve Jobs summarizes this situation.

Steve Jobs: Object-Oriented Software

- *Once you understand objects, its clear that all software will eventually be written using objects. Again, you can argue about how many years it will take, and who the winners and losers will be during this transition, but you can't argue about the inevitably of this transition.*

  Objects are just going to be the way all software is going to be written in five years or-pick a time. It's so compelling. It's so obvious. It's so much better that it's just going to happen.

Wired. (1996, February). p. 102.

Miscellaneous Other

- This section contains a number of brief news items that do not fit well into the other categories used in this chapter. Each gives a hint of things to come.

Deep Blue Falls to Kasparov

- *World chess champion Garry Kasparov has won the six-game match against the IBM super computer called Deep Blue. Counting tie games as a half point each, the final score was Kasparov 4, Deep Blue 2. Kasparov will receive $400,000 for winning the match; the IBM team representing Deep Blue says it will put its $100,000 loser's award into more research.*

Atlanta Journal-Constitution. (1996, February 18). p. A1.

Note: In a rematch that took place in May 1997, Deep Blue defeated Kasparov.

Deep Blue Debriefing

- *IBM's Deep Blue computer was programmed to evaluate a total of about 20 billion moves within the three-minute window allotted for each move in a formal chess match. That capability is enough to consider every possible move and countermove 12 sequences ahead and selected lines of attack as much as 30 moves beyond that. The fact that this omniscience was not enough to beat a mere human is "amazing," says one of Deep Blue's programmers. The lesson here, says another, is that chess masters such as Kasparov "are doing some mysterious computation we can't figure out." Still, the IBM team got what it needed out of the match-their goal has always been research to show how parallel processing can be used for solving complex problems such as airline scheduling or drug design, not to be world chess champions. After all, this *is* IBM, says an IBM PR person.*

Scientific American. (1996, May). p. 16.

Given a specific enough problem, computers can do very well. Deep Blue is a worthy competitor for the world chess champion. In terms of flexibility and ingenuity, however, humans are far better than machines. This will continue.

The amount of computing power in Deep Blue will eventually become commonplace in medium-priced computers Thus, we need to consider what kinds of problems can be addressed by the routine use of so much computing power. For example, the type of computing power in Deep Blue can be applied to problems such as weather forecasting.

Career Change for Deep Blue

- *Freshly laid off following its loss to Garry Kasparov as a chess opponent, IBM's Deep Blue computer has a new job-as a weather forecaster. Deep Blue will assume its new post this summer, providing up-to-the-minute weather updates to Atlanta's Summer Olympics athletes and spectators.*

Information Week. (1996, May 27). p. 12.

The Ever-Morphing PC

- *"The PC will fade into the background as we deliver technologies that allow people to focus on their jobs, as opposed to focusing on the computer's user interface," says Stephen Boies, head of IBM's interactive systems division at the Thomas Watson Research Center. For instance, IBM is developing a specialized device that car dealers can plug into their telephone line to get credit approval for their customers in under two minutes. And physicians and nurses at Long Beach Memorial Medical Center in California use touch-screen flat-panel displays embedded in the hospital's walls to track patients' progress. Apple Fellow Donald Norman predicts that we're seeing the dawn of computing's next generation: "We're at the end of the second generation of the personal computer," which was marked by the graphical user interface, promising ease of use. "But what happened," says Norman, "is computers have become even more complex, expensive, and unmanageable." In the third generation, "the focus will be on people and the tasks they want to accomplish, not technicalities."*

Information Week. (1996, September 23). p. 48.

Forget the Home PC-Now It's the "Information Furnace"

- *As computer companies and industry analysts look toward the future of home computing, they're predicting that stand alone desktop units will give way to a micro version of a client-server network, with one central server computer connected to several home-based clients. Compaq and IBM are both working* *toward this vision-IBM has introduced a new line of Aptiva computers featuring a minitower that can be positioned separately from the compact console that houses the CD-ROM and floppy drives and their power controls. Compaq is working on a wireless network solution so that homeowners don't have to worry about pulling cable through their walls. Hewlett-Packard has dubbed the concept an "information furnace" that runs the rest of the household. "All of these devices will one day be interconnected using a high bandwidth home network that is easy to install, maintain and expand," says HP's senior VP for R&D. "Many of the technologies needed to realize the vision of a home information furnace and its attendant network are available today."*

Investor's Business Daily. (1996, October 15). p. A8.

Picture Phone Makers Target Desktop Video

- *With prices of all computer-related peripherals continuing their downward spiral, desktop video conferencing equipment is no exception. A group manager for Connectix, a software company that sells a video-phone system for $150, says: "Within five years, every PC will have a built-in camera." Elliott Gold, who's covered the teleconferencing business for years, says, "We still don't know if people really want picture phones," but predicts that whether or not they want it, desktop video communications "will sneak up on them, like fax did."*

Wall Street Journal. (1996, February 27). p. B1.

Conclusions and Recommendation

- Essentially all progress in information technology is being driven by forces outside of education. That is, the education market is small and its technical demands are small, relative to business, government, and the military.

  However, the "trickle down" effect is immense. The super computer of today is the medium-priced computer 20 years from now. The best of network connectivity of today will be in homes and schools 20 years from now.

The challenge is to educate today's students for their roles as responsible adult citizens and emerging leaders.

The next chapter contains a number of forecasts for the future of information technology in education

<<< Chapter 5 Contents Chapter 7 >>>

Return to Cover Page

<<< Chapter 6 | Contents | Chapter 8 >>>

Chapter 7
Forecasts for Technology in Education

- The future of information technology in education is harder to forecast than the general future of information technology. One difficulty is that students and teachers do not control the school budget. As pointed out by Seymour Sarason (1990), they lack power. Another difficulty is that education does not easily change. It is a complex social system. For these reasons, the forecasts or predictions in this section are made with far less confidence than those in the previous chapter.

  By and large, the forecasts given in this section are optimistic. They are forecasts of our educational system effectively coping with the changes being wrought by technology. They are forecasts of students getting a better education. Many of the ideas discussed in this section were previously discussed in Moursund (1992).

Eleven General Forecasts

- This section contains brief discussions of 11 different forecasts for information technology in education. In many ways, these are linked to the goals for information technology in education discussed in Chapter 4. In essence, we are in a situation where the underlying science and technology (see Chapter 6) make it technically possible to achieve the goals listed in Chapter 4. There are a number of underlying driving forces that are contributing to schools adopting some or all of the goals. The commitment of resources, if it continues to grow, will cause the forecasts given in this chapter to be accurate.

Student Access to Computing Power

- The total amount of computing power available to students is growing quite rapidly, and this growth will continue for many years to come. The growth comes from two main sources:

1. The number of microcomputers in schools and in the homes of students is continuing to increase. Eventually the great majority of students will have routine access to a portable microcomputer that they carry between home and school. These portables will have easy-to-use interfaces with more powerful microcomputers that schools will make available to their students.

2. The capabilities of the microcomputers available to students are increasing at a rapid pace.

In the United States at the current time, schools have approximately one microcomputer per eight students. However, there are a number of school sites in which the ratio is approximately one microcomputer per student, or even better. The number of such sites will increase relatively rapidly during the next decade.

Connectivity

- The megatrend toward providing students and teachers with connections to the computer networks of the world is well underway. Increasingly, educational leaders and policy makers agree that students should have connectivity to other students within and beyond the school building, and to the information sources of the world.

  There is considerable agreement that libraries will become "virtual libraries"-that is, that library contents will be distributed electronically throughout the world, rather than being physically available only in isolated buildings. Such libraries will be accessible to students both in the classroom and at home. This represents a major change in the world. Already, students of all ages are learning how to make effective use of libraries that previously had only been available to a select few researchers.

  The pace of increased connectivity is faster in the business world than it is in the home market. It is faster in the home market than it is in schools. When all three markets are taken together, it seems clear that both our formal and our informal educational systems will experience continued rapid growth in connectivity for many years to come. In terms of the S-shaped growth curve (see Appendix), we are beginning to enter a time of very rapid growth. It appears that this period of rapid growth will extend over many years.

  Of course, there is a substantial difference between providing schools with the connectivity and thoroughly integrating effective use of this connectivity into the curriculum. The needed investment in teacher training and curriculum development will be slow in coming. Teacher training remains a major impediment to the rapid increase of effective use of information technology in schools.

Artificial Intelligence

- Computers will continue to get "smarter." That is, they will grow in their capability of doing intelligent-like things. More and more problems will be solved by merely expressing the problem in a format that fits the computer's capabilities. Increasingly, the human-machine interface will make it easier to do this, and the interface itself will make use of results developed by the field of Artificial Intelligence.

  There are now thousands of expert systems in everyday use. These systems are computer programs based on past successful solutions to particular problems. They have a level of "intelligence" adequate to help accomplish tasks and solve problems within a narrow scope. Such expert systems are "fragile"-that is, they only perform well within the narrow domains they were designed for. This means that people using such expert systems have to have a good knowledge both of the domain of the expert system and how to recognize a problem outside of that domain.

  The capabilities of such expert systems will continue to increase. They provide excellent examples of where a person and a computer who are trained to work together can outperform either working individually.

  Problems will increasingly be solved by teams composed of humans, computers, and computerized equipment such as robots and automated factories. It takes considerable knowledge and experience for a human to be an effective member of such a team. The capabilities of two of the team members (the computer and the automated equipment) will continue to increase rapidly. This places an added burden on the human member of the team. The human provides a unifying sense of purpose and perspective, and defines the overall task and the goals. This role is indispensable.

  Education is faced by the problem of educating people to become integral members of the three-part team consisting of humans, computers, and automated equipment. This is not an easy educational task; it is one that our educational system has so far done little to address. In many cases the human component of this three-part team will, itself, be a team. Our schools have made substantial progress in cooperative learning-teams of students learning to learn together. Far less progress is occurring in helping students gain skills in collaborative problem solving.

Other aspects of Artificial Intelligence will have a profound impact on education. Voice input provides an example. Already, voice input is widely used in the commercial world. Educators have little insight into how to teach reading and writing in an environment that includes high-quality voice input and voice output systems.

Hypermedia

- Hypermedia is an interactive environment that includes text, color, voice, sound, graphics, and video. Hypermedia allows user interactivity in the information retrieval process. Users can choose individual pathways through information collections, and the information itself can be presented in multiple formats that better fit the needs of individual users. Increasingly, information is being stored in a hypermedia format, and this trend will continue.

Schools are embarking on a pathway in which all students will become proficient in reading (that is, using) hypermedia. Students are learning to retrieve information stored on CD-ROMs, in hypermedia computer files, in computerized databases, and on the Internet's World Wide Web. Eventually, such electronic access to hypermedia-based information will be commonplace.

Schools are also embarking on a pathway of having students learn to write (create) hypermedia documents. The trend is clear. Eventually, schools will take it for granted that reading and writing mean both the conventional paper-based and also hypermedia-based activities. However, interactivity, sound, color, still photography, computer-based drawing and painting, and video add new dimensions to communication. In total, facilitating students in developing basic skills in reading and writing hypermedia will prove to be a major challenge to our educational system. Given the limited resources and time that teachers have for acquiring and integrating these new skills themselves, schools will probably be slow to provide extensive hypermedia learning opportunities to students.

This will tend to create a situation in which some students become facile at reading and writing hypermedia, while other students develop only a reading skill in this area. As the hypermedia literate students progress through our school system, they will present a major challenge to their teachers. For example, if a teacher lacks skills in writing hypermedia, how will the teacher adequately assess the work of students that is presented in this format? How will the teacher help such students increase their skills in communicating in hypermedia?

Productivity Tools for Students

- The generic and specialized computer productivity tools for adults will continue to get better and will become better interconnected. Increasingly, similar tools will be integrated into the content of the K-12 curriculum. Students will grow up using the computer productivity tools of adults. Curriculum content will reflect the capability of these productivity tools.

  As noted elsewhere in this book, curriculum content and tools used to solve problems and accomplish the tasks of a discipline have always been interwoven. This will continue as computers become commonplace in the schools. Thus, we will see substantial changes in the content of the various disciplines. Some will be more affected than others, depending on how powerful the computer tool is in each particular discipline.

  Because of the pace of change of overall computer capability, there will be an increased pace of change of curriculum content. The content will adjust to the capabilities of computers as an aid to solving the problems and accomplishing the tasks of the discipline.

  We already see this, for example, in accounting and graphic arts coursework. The advanced math curriculum in high schools is increasingly being driven by the capabilities of handheld graphing calculators. Eventually, this calculator-driven curriculum will become a computer-driven curriculum. Because students are not limited to problems easily solved with pencil and paper, they can approach more sophisticated content earlier in their educational careers. Similar statements hold for science courses-especially those that make substantial use of mathematics.

  Progress in thoroughly integrating student productivity tools into the curriculum will be slow. It requires substantial investments in teacher training, curriculum development, and the assessment system. All three of these areas of needed capacity building are currently underfunded and will continue to be underfunded.

Teacher Productivity Tools

- Many different computer tools can help increase teacher productivity. Examples include word processor, electronic gradebook, databases of exam questions, lesson plans stored in a word processor, and so on. Access to the Web gives teachers access to subject matter information and lesson plans. There has been and will continue to be a steady increase in teacher usage of such productivity tools.

  There is a different class of teacher productivity tools-ones that may enhance student learning and teacher effectiveness. These are the desktop presentation tools and other electronic aids to teachers interacting both with students and the curriculum in a classroom setting. We can expect substantial growth in use of teacher productivity tools.

  For example, a classroom can have Internet connectivity. During a discussion between students and the teacher, either the students or the teacher may retrieve information from remote databases or from people. This type of classroom computer use is now in its infancy; it will grow rapidly in years to come.

  As a second example, consider a package of mathematics software that the students are learning to use. With appropriate desktop presentation projection equipment and a computer, the teacher can interact with the whole class or with small groups of students, demonstrating key features of the software. Samples of student work can be displayed and discussed. Students and teacher can work together to explore problems, making use of the computer capabilities.

  A third example is provided by having students and teachers interact electronically. Assignments and materials can be provided to students through this electronic highway. Questions can be asked and answered. Assignments can be submitted and then returned electronically.

  Finally, consider computer-assisted learning and other aids to student learning. Teacher productivity can be increased by relegating certain instructional tasks to such facilities.

Technology-Enhanced Learning

- Several of the components of computer use as an aid to learning are coming together to form a combination we call technology-enhanced learning (TEL). TEL consists of:

1. The combination of computer-assisted learning (with built-in computer-managed instruction), distance education, and electronic access to both information and people.

2. Aids to teacher interactivity with students and student interactivity with each other, such as desktop presentation, e-mail, and groupware.

3. Increasingly powerful student productivity tools with built-in learning aids, context sensitive help, templates, and other aids to producing high-quality products. These help a user to learn while doing.

Via TEL, more and more education will happen at a time and place that is convenient to the needs of the learner. Convenient education is a megatrend in formal and informal education.

"Just-in-time" education is a second aspect to this TEL trend. Some learning tasks take years; it is not possible to master a second language just at the point you need to communicate in it. However, many other learning tasks can be completed in a few minutes, a few hours, or a few days-just in time to apply the skills when needed. How rapidly and effectively the learning occurs depends on the background and capabilities of the learner and on the learning environment. Our educational system needs to help students gain increased skill in being "just-in-time" learners. This is an important component of learning to learn and being a lifetime learner.

A third aspect of TEL can be found in the changing capability of the informal educational system. Almost all general-purpose home computers that people purchase today come equipped with a CD-ROM drive. Microsoft's Windows 95 operating system contains built-in support of telecommunications. The trend is clear. Technology-enhanced information access will increasingly allow homes, businesses, and other informal education environments to support just-in-time and convenient education. As the amount and quality of convenient education materials continue to increase, there is the potential that more and more of the traditional content of formal education will be learned in informal educational settings. The role of formal education-and of the teacher-will change.

We can get a glimpse into potential changes by asking ourselves what are the unique characteristics of a human "live" teacher, as contrasted with CAL, CMI, distance education, and other electronic aids to learning. While there are many answers, several of the most important ones are:

1. The human-human interface. This is far better than any current human-machine interface. Teachers can know their students and interact with them in a manner appropriate to the needs of human beings.

2. The versatility of the human teacher. A human teacher can facilitate an interdisciplinary discussion that ranges over whatever comes to the minds of the students and the teacher. The human teacher has flexibility and capabilities that far exceed those of any current computer system in this regard.

3. The social aspects of education. Education is a social activity. Human teachers, along with the interactions among students and with teachers, are essential to our formal and informal educational system.

This type of analysis suggests that our formal educational system will place more of its structured efforts into making effective use of the uniquely human characteristics and strengths of human teachers. More of the subject matter content and rote skill components of the curriculum will be left to TEL.

Curriculum Content

- Increasingly, computers can solve or help solve the types of problems that students study in school. The usefulness of computers as an aid to problem solving cuts across all academic disciplines. However, computers are far more useful in some disciplines than others. For example, while computers are useful tools in both art and music, they are more central to accounting, mathematics, and science.

  To date, the content of the K-12 curriculum has not changed a great deal due to computer technology. We have previously mentioned the growing role of calculators in mathematics instruction, and the toehold of the microcomputer-based laboratory in science education. The use of computer simulations and simulation games is slowly growing. Through the use of such simulations, individual students or a whole class can explore complex problem-solving situations in business, science, and social science.

  Another example is provided by students learning to use electronic aids to retrieving information. Instruction in the electronic accessing of information is replacing instruction in non-electronic ways to access information. It is now clear that all students need to develop some of the information retrieval skills of a research librarian. Instruction in such skills can begin at the primary school level.

  We will see a slow but steady change in the content of all academic curriculum areas due to information technology. The pace of this change will accelerate as computer facilities become more readily available to students and teachers, and as each group becomes more skilled in their use.

Preservice Education of Teachers

- The National Council for Accreditation of Teacher Education (NCATE) is the main accreditation agency for Colleges of Education in the United States. NCATE is making continuing progress toward accreditation standards that will require both preservice teachers and their faculty to become computer literate. This is a trend that will continue.

More and more preservice teachers have had a number of years of computer experience while they were in the K-12 educational system. Thus, the average level of computer knowledge of preservice teachers is steadily increasing. This trend will continue.

Taken together, the two trends of this section ensure that there will be a continuing increase in the computer knowledge and skills of graduates of teacher training programs. However, this steady improvement needs to be compared against the steadily increasing capabilities of information technology in education. Right now, there is a huge gap between the needed knowledge and skills of recently graduated teachers, and their actual knowledge of computers in education. It appears likely that this gap will continue to exist-indeed, it seems likely that it will grow.

Inservice Teacher Education

- One way to talk about a particular specialized education is to quantify its "half-life." Suppose that a person gains the knowledge and skills to be fully qualified as a neurosurgeon or a cardiologist. Suppose that this person then gains no new knowledge or skills, while the contemporary standards continue to increase. How may years will it be before this person is only "half-qualified?" While such a quantification is not particularly scientific, it does provide a basis for analysis and discussion. The half-life of a neurosurgeon or a cardiologist might be in the range of 3 to 4 years.

  What is the half-life of a teacher's education? How is it affected by the rapid pace of change in the totality of human knowledge or by changes in technology? Although we do not have precise answers, it is clear that the rapid pace of change in technology has greatly shortened the half-life of a teacher's education.

  At one time, it was common for teachers to obtain lifetime teaching certificates. In more recent years, most states have put in requirements that a teacher have some continuing teaching experience and a certain amount of coursework or other training for certificate renewal.

Information technology in education has added a new and perplexing dimension to this picture. Information technology is affecting both the content and the pedagogy of every discipline at every teaching level. Moreover, it is not easy to develop the needed knowledge and skills effectively to integrate the technology into the everyday curriculum. The facility with which some students pick up technology skills often serves to increase pressure on the educator, as traditional roles of teacher and learner are disrupted.

Our inservice teacher education system was not designed to deal with a rapid pace of change. It is proving inadequate in dealing with computer-based technology. Unless there is major restructuring in our inservice education system, there will be a growing gap between the potentials of information technology in education and the actual implementation. At the current time, there is little indication that the needed restructuring of our inservice education system is occurring.

The analysis of preservice and inservice teacher education leads to a forecast of a continuing major gap between information technology knowledge and skills needed by teachers and their actual knowledge and skills.

The School-Home Connection

- Computers and connectivity are having a significant impact on the "home" part of our formal and informal educational system. Current estimates are that close to half of the school children in this country have access to a computer at home. This suggests that there are several times as many computers in the homes of school-age children as there are in our schools. It also means that there is substantial inequity in students having access to the technology. Those students who come from a home situation where there is a computer and parents who know how to make effective use of a computer may be receiving several times as much instruction and experience with computers as those students from other homes.

The following two news items suggest that computers and connectivity will continue to grow in the homes of school-age children.

Education is Key to Home PC Market

- *An American Learning Household Survey says that over 80% of intended family household PC buyers in its study cited children's education as the primary reason for purchase, relegating work-at-home and home financial applications to a distant 40% level. The survey also found that children's use of the PC is shifting away from games and toward more complex uses of the computer as an information access tool.*

The Red Herring. (1995, December).

Sega Will Add Browser to Gaming Equipment

- *Sega Enterprises plans to add equipment to its Saturn video game console that will enable consumers to browse the Internet on their TV set. The entire package would cost between $100 and $150 more than the current $299 Saturn price tag.*

Investor's Business Daily. (1996, February 16). p. A30.

The news item about Sega Enterprises is especially interesting, as it suggests that we may move rapidly toward integration of entertainment and non-entertainment systems. The computing power in a game machine rivals or exceeds that in many of the general purpose microcomputers. Such computing power can be used for more than just playing games.

Educational software developers are well aware that there is both a school market and a home market for their software. Increasingly, these developers have come to realize that the home market may exceed the school market.

Of course, the home and the school markets for educational software are by no means the same. The term *edutainment* has been developed to describe software that has a combined educational and entertainment focus. If an educational product is being developed primarily for the home market, the entertainment components may well dominate over the educational components. There is relatively little solid research to support the educational value of many of the educational games that are widely sold to parents and children.

Conclusions and Recommendation

- As you make use of the educational technology forecasts in this chapter, keep in mind that they are mainly forecasts based on expert opinion. Each forecast represents a potential-something that schools could be doing right now. One can summarize these forecasts by asserting that the student and teacher goals for information technology given in Chapter 4 will eventually be achieved. These goals will help guide our educational system over the next few decades.

  The forecasts have a unifying theme-moving from first-order effects to second-order effects. Some schools and school districts will move much faster than others. However, it seems clear that our educational system as a whole is going to move toward the second-order effects, and then beyond them.

  These will produce substantial disruptions in our current educational system. The planning and change process needs to be given careful attention. Strategic planning is discussed in Chapter 9.

  The next chapter considers some of the ramifications of moving our curriculum, instruction, and assessment in the forecast directions.

<<< Chapter 7 Contents Chapter 9 >>>

Chapter 8
Some Speculations

- This chapter is somewhat more speculative than earlier chapters. It suggests that we are just at the beginning of truly major changes in our educational system, and it briefly explores some possible changes.

A Large Investment is Needed

- Over a period of many years, American businesses invested many hundreds of billions of dollars in computer technology. Initially, it seemed they gained little to show for this huge investment. Annual productivity gains in this country continued at a modest rate.

  And then-finally-it all began to come together. Productivity in this country began to increase at a higher rate. The United States topped the world in worker productivity. What happened is summarized in the following brief news item.

  Complementarity is Key to IT Productivity

  - *Researchers at Columbia, Carnegie Mellon and MIT have come up with a new explanation for the apparent disengagement between increased investments in computer technology and productivity gains. The key to discerning productivity increases attributable to use of information technology is "complementarity"-a theory that postulates that productivity gains from expanded use of technology cannot occur in the absence of a number of corresponding developments, such as the introduction of more flexible workplace structures, more delegation of responsibility to lower-level workers, increased skills training for workers and managers, and the installation of new infrastructure, such as Internet connections and "smart" buildings. New research shows that when these complementary factors are taken into consideration, investments in information technology do stimulate productivity and growth.*

  Technology Review. (1996, October). p. 65.

  Our educational system has a long way to go before it begins to match the level of information technology investments that businesses have made. Significant educational gains cannot be expected from the small investment that has been made so far. In addition, significant educational gains will require empowering students and empowering teachers-a significant change from the top down system that is currently in place.

Some Changes in Higher Education

- Precollege education has led higher education in the integration of information technology into the classroom. However, higher education will lead precollege education in the major changes that can come through technology-enhanced learning (TEL). There are a variety of reasons for this. One is that precollege education has more of a custodial responsibility for students than does higher education. The second is that students in higher education are able to and are allowed to take more responsibility for making decisions about what courses they will take, when and where they will study, and so on. A third reason is that higher education is used to competing for students and has more of an entrepreneurial attitude than does K-12 public education.

  A typical institution of higher education has a campus-buildings and grounds that facilitate a number of people living relatively close together, coming together to study and do lab work, and share their learning experiences. Some of the physical facilities are quite expensive and have an economy of scale. This is certainly true of scientific research facilities, labs, libraries, and athletic facilities. At one time it was true of computer facilities; even now, the "Computer Center" is typically a prominent building on campus.

  Many of the various school reform movements suggest that education should be run more like for-profit businesses. The past few years have seen a nationwide slowdown in public funding for higher education. Higher education has responded by becoming more "businesslike"-more entrepreneurial. However, we are just at the beginning of major changes as higher education becomes even more entrepreneurial. The following news items give some indication of how information technology will affect higher education.

  Changing Role of the University

  - *Columbia University professor Eli Noam sees a reversal in the historic direction of information flow: "In the past, people came to the information, which was stored at the university. In the future, the information will come to the people, wherever they* *are. What then is the role of the university? Will it be more than a collection of remaining physical functions, such as the science laboratory and football team? Will the impact of electronics on the university be like that of printing on the medieval cathedral, ending its central role in information transfer? Have we reached the end of the line of a model that goes back to Ninevah, more than 2500 years ago? Can we self-reform the university, or must things get much worse first?"*

Science. (1995, October 13). p. 247.

The Future of the University

- *Eli Noam, director of Columbia University's Institute for Tele-Information, says in the new issue of Educom Review that "many of the physical mega universities ❩ are not sustainable, at least not in their present duplicative variations." Noam predicts that "ten years from now a significant share of conventional mass education will be offered commercially and electronically." The home page for CITI is <http://www.ctr.columbia.edu/vii>.*

Educom Review. (1996, July/August). p. 38.

Eli Noam sees major changes occurring in higher education. Distance education will begin to siphon off "traditional" students. Profit margins on the distance education students will be less than for conventional students. University physical facilities will start to be underutilized. The cost of maintaining such infrastructure is, to a large extent, independent of its level of use.

The net result is that many colleges and universities will experience fiscal problems. They will not generate enough income to maintain their physical facilities. Once a fiscal downward spiral begins, many colleges and universities will need to make major changes in their on-campus programs or go out-of-business.

The competition that is shaping us comes not just from individual colleges and universities. A multi-state development of such competition is going on in the western United States.

Virtual University Slated for 1997

- *The Western Governors' Association, led by Gov. Roy Rohmer of Colorado and Gov. Mike Leavitt of Utah, are rapidly pulling together plans for a Western Virtual University and now say they expect to begin admitting students by the summer of 1997. The Education Management Group, a subsidiary of Simon & Schuster, has donated $150,000 to the planning effort.*

Chronicle of Higher Education. (1996, February 16). p. A21.

California Shuns Virtual University

- *California will not participate in the Western Governors' "virtual university" project. Instead, Gov. Pete Wilson says the state may start its own program to create and market college courses through the Internet. He's enlisted the help of the state's three public-college systems, along with the presidents of Stanford University and the University of Southern California, and executives from the computer, finance and telecommunications industries in the planning process. Unlike the Western Governors' project, the California venture will not seek separate accreditation. "The control of the academic offerings and the control of the curriculum would remain with the campus," says a CSU VP. "We do feel that faculty should be in charge."*

Chronicle of Higher Education Academe Today. (1996, October 3).

Berkeley, California

- *Supported by a $2 million grant from the Alfred P. Sloan Foundation of New York, University of California, Berkeley says it will launch one of the largest educational online projects in the history of the Internet. Within three years, Berkeley Extension*

Online will offer 175 college courses focusing primarily on continuing adult education. Berkeley Extension Online will be developed in collaboration with UC Berkeley Extension's Center for Media and Independent Learning (CMIL). UC Berkeley Extension is the continuing education arm of the University of California at Berkeley and one of the largest continuing education providers in the country. Currently, Extension offers 25 courses through America Online. Noting the rapidly growing success of the Internet, Mary S. Metz, Dean of UC Berkeley Extension, said, "Study after study has shown that, for many adults, continuing education has become an imperative in today's rapidly changing world. But continuing education must be provided in formats, locations, and time frames that fit the demanding work and personal lives of adults. Distance education, including courses online, offers a marvelous opportunity for adults, because it eliminates problems such as travel time and fixed class schedules that can make it difficult for them to take courses."

(Press Release: 1996, June 17.)

The trend toward distance education is a worldwide phenomenon. As suggested by the following news items, it is being strongly driven by financial considerations.

Teacherless Classrooms Considered in Canada

- *Ontario's Community colleges, hunting for $120-million in savings for the next academic year, are de-emphasizing the role of the teacher in the learning process. A study prepared for the Colleges' Council of Presidents titled "Learning Centered Education" says educational institutions can cut teaching costs by using CD-ROM courses and computer tutorials to deliver education, using support staff rather than teachers to monitor students' progress.*

Ottawa Citizen. (1996, January 17) p. A4.

Educational Software

- *The Software Publishers Association predicts the K-12 educational technology market will grow from $2.6 billion in 1993-94 to $4.5 billion by 1999. A significant increase is also expected in the development of commercial software for higher education use. Educom president Robert C. Heterick Jr. says the ways to reduce the cost of higher education (which has tripled over the last decade, largely because of teacher salaries) is through the use of information technology in the colleges and universities: "Today you're looking at a highly personal, human-mediated environment. The potential to remove the human mediation in some areas and replace it with automation-smart, computer-based, network-based systems-is tremendous. It's gotta happen." Heterick says the likeliest candidates include courses such as basic math, English and science.*

New York Times. (1996, July 29). p. C5.

MA in Open and Distance Education

- *The Open University is to teach an international Master's in Open and Distance Education as from February 1997.*

  Open and distance education is increasingly important as a teaching and learning mode all over the world. A widely-recognized qualification in this field is desirable if you are pursuing a career with one of the many institutions using or developing open and distance education systems.

  The Open University of the United Kingdom is one of the most respected practitioners, and its Institute of Educational Technology will offer the MA (Open and Distance Education) using electronic media and print.

  The course will be based on the Institute's wide experience of developing open and distance teaching and its top-rated research. The content includes a balance of knowledge and skills, constantly updated by online tutoring.

  To take this programme you must:

- *Be able to receive the materials via postal or courier services.*
- *Have access to the Internet and World Wide Web.*
- *Have use of a PC with a CD-ROM drive.*
- *Pay, or have paid for you, the fees (in 1997, 2,250 pounds sterling for Year 1) plus telecommunications charges from your end.*
- *Hold a first degree and be proficient in English.*

Surely, this is a sign of things to come. The Open University of the United Kingdom may become the leading institution in the world for master's degree programs in distance education. This is a "natural" because the Open University is a distance education university, and so has accumulated a great deal of research and practical knowledge in this area.

In a few years, we will see more and more of these "natural" distance education programs. Are you interested in studying the early history of the USSR? Perhaps one of the Russian universities will come to dominate the worldwide market for distance education in this area. Similarly, one might expect one of the great universities in Mexico to dominate the world market for distance education specifically focusing on ancient Mayan culture.

The Precollege Education Business

- Higher education has always been somewhat of a competitive business. College age students have a choice of where they will go to school. This is much less true for K-12 students. But, that is changing.

  Distance education has long been one of the options at the K-12 level. Some students live so far from a school that their only options are going to a boarding school or getting their education while staying at home. In the latter case, some combination of distance education and home schooling is common.

Distance education is also of growing use in conventional K-12 schools. The technology makes possible a broader range of coursework that the school site can provide. For example, suppose a school has a half dozen students who want to study a particular foreign language or an advanced course in science or mathematics. It is likely cheaper to do this via distance education than through offering a small class. Moreover, many schools are unable to find a suitable teacher for such specialized courses. Thus, K-12 distance education is a growing business.

The previous section focused on distance education in higher education. A number of precollege students are well qualified to take college courses. Distance education initiated by higher education is beginning to provide a form of competition for precollege education. Notice how this idea is represented in the following news item about the Governor of Wisconsin.

Wisconsin Governor Wants to Get Wired

- *The governor of Wisconsin used his annual State of the State address to present plans for a $10-million project to link all 26 public university campuses in the state via computer, and to begin offering high school classes online by 1997. The University of Wisconsin system already offers Advanced Placement courses in mathematics and engineering via the Internet, as well as nursing courses to adult learners.*

Chronicle of Higher Education. (1996, February 23). p. A21.

Distance education and computer-assisted learning are being merged in many Web-based courses. This is a trend that will continue. Moreover, the Internet can be viewed as a rapidly growing library. Access to the Internet and a few commercial CD-ROMs can give students better resources than are found in a typical school library. A surprisingly wide variety of high quality information is becoming available through the Web.

IBM Offers Free Patent Database on Web

- *IBM plans to make the content of 2 million U.S. patents (from 1971) available free on the Web site <http://www.ibm.com/patents/>. Various companies provide patent access for a fee; one company, Questel-Orbit (a division of France Telecom) charges $1,995 a year, and a company executive says: "I still believe that we have the most robust search engine."*

New York Times. (1997, January 9). p. C3.

Free Hollywood Classical Films

- *The American Film Institute, setting another CyberSpace milestone, has announced it will start presenting classic films over the Internet in their entirety for the first time later this month.*

  The organization, one of the leaders in promoting movie preservation, will launch AFI Online Cinema on Jan. 22 with the 20-minute Charlie Chaplin comedy "The Rink," released in 1916, complete with a musical score. The site is <www.afionline.org/cinema>.

The Register-Guard. (1997, January 19). p. C4.

Digital Libraries: The Future

- *The vision of computers powerful enough to organize and index huge treasure troves of scientific literature using intelligent functions such as "vocabulary switching"-classifying an article that mentions "Unix" under "operating systems" even if the words "operating systems" do not appear in the article-is finally coming to fruition, 32 years after it was first outlined in J.C.R. Licklider's "Libraries of the Future" (1965). Large-scale simulations on the HP Convex Exemplar supercomputer at the National Center for Supercomputer Applications have* *resulted in generating concept spaces for 10 million journal abstracts across 1,000 subject areas covering all engineering and science disciplines-the largest vocabulary switching computation ever achieved in information science. Future developments will require automatic indexing with scaleable semantics to coordinate searches among the one billion repositories likely in the next century.*

Science. (1997, January 17). p. 327.

Digital Library Transition Will Take Awhile

- *Project TULIP (The University Licensing Program), a five-year experiment in providing online access to scholarly journals, has concluded, and the results indicate that the transition from conventional to digital libraries will take much longer and cost more than commonly thought. "A common view, which all TULIP participants share, is that the transition to a digital library will go slower than they had expected before starting the project," says the project's final report, which emphasizes the need for faster speeds and increased storage capacity on campus networks. In addition, the project found that it's important for institutions to know what library users want, and to promote electronic access to raise awareness on campus. The report is available at <http://www.elsevier.nl/locate/tulip/>.*

Chronicle of Higher Education. (1996, August 16). p. A21.

A few of the likely outcomes of rapid growth in global digital libraries and TEL include:

- There will be a major decline in the school library as a repository of information.

- It will become common for students to use TEL. Students will be encouraged to learn how to learn in this environment as part of becoming self-sufficient lifelong learners. Students will have more options in what they study, as well as where and when they study it. An increasing number of students will take courses during evenings, weekends, holidays, and summers-while sitting at home or at vacation locations.

- TEL will make it easier for parents to home-school their children or to design a program of study that replaces a significant portion of the traditional school program. We can expect home schooling to increase.

- Charter schools will proliferate. Charter schools are paid for by public funds, but have some of the characteristics of private schools. They face less of a bureaucratic nightmare than do the public schools. Often they have a particular academic orientation, such as arts or sciences. TEL makes it possible for a relatively small charter school to offer a broad based curriculum.

- There is apt to be a proliferation of small private schools. By making extensive use of TEL, a small private school can offer a broad based curriculum without having a broad based (and expensive) staff.

Computer Tool as Course Content

- There is a rapidly growing discrepancy between the capability of the computer-as-tool in various disciplines, and the curriculum content of these disciplines. Computer tools are embodying a significantly increasing part of the content of various disciplines. Professionals in all academic fields are learning to make routine use of information technology to solve problems and accomplish tasks in their disciplines.

  The educational goal is to prepare students to play an appropriate role in Person Plus, as described in Chapter 5, as an aid to posing and solving problems. Our current educational system is ill-equipped to keep up with the rapid changes in discipline content being brought about by information technology. The hardware, software, teacher training, curriculum development, and assessment are all falling further behind in disciplines that are driven by information technology.

There are a variety of solutions to this problem. The most obvious are allocation of more resources-which most schools find difficult to do. On an inflation-adjusted basis, public school funding has been nearly flat during the past 5 years, and appears likely to remain so during the next 5 years.

Other approaches include empowering students and facilitating teachers to learn on the job, especially by taking advantage of rapidly growing student knowledge and skills. Students have the time and energy to learn the "latest and greatest" software applications, and then help each other and their teachers to learn.

Conclusions and Recommendation

- Student access to TEL, the Internet, and to other students throughout the world will place significant pressure on teachers and our conventional school system. The teacher as "Sage on the stage" is going to give way to the teacher as "Guide on the side." Students will learn to take more responsibility for their own learning and for assessing their own progress. Informal education settings (home, community organizations, science and technology museums, places of work) will play an increasing role in education of students.

The next chapter explores the topic of long-range strategic planning for information technology in education.

<<< Chapter 7 | Contents | Chapter 9 >>>

Return to Cover Page

Chapter 9

Planning for Educational Change

- Our educational system is complex, massive, and highly resistant to change. It takes a major and continuing effort to produce a significant change in our educational system. This chapter begins with a discussion of how information technology is affecting the conventional goals of education. It then focuses on long-range strategic planning and its role in educational change.

Goals of Education in the United States

- A strategic plan for technology in education should take into consideration the generally acknowledged goals of education. Chapter 3 contains three general goals of education. The following list is more extensive and detailed. It is a list of goals that many people in American society generally agree upon. Each of the goals is followed by brief comments about how the goal is being affected by information technology.

Conserving Goals

- G1 Security: All students are safe from emotional and physical harm. Both formal and informal educational systems must provide a safe and secure environment designed to promote learning.

  Comment: There has been a great deal of media coverage about potential physical and emotional harm that might occur as students are given access to the World Wide Web. Schools are responding by trying to shelter students from Web sites that are deemed to be inappropriate. In addition, students are being asked to use the Web in a responsible manner.

  G2 Full Potential: All students are knowingly working toward achieving and increasing their healthful physical, mental, and emotional potentials.

  Comment: Notice the emphasis on students "knowingly" working to increase their potentials. The goal is to empower students to empower themselves. Person Plus is more powerful than a person who lacks knowledge and skills in using the modern mind tools. Achieving full potential includes learning to make effective use of contemporary tools that are used in the fields where one is developing their potentials.

G3 Values: All students respect the traditional values of the family, community, state, nation, and world in which they live.

Comment: Not all people are equally appreciative of and supportive of information technology. Our educational system must allow for such differences in values. In many cases, this means that students must be given options on assignments and on information sources, as well as guidance in selecting options that are supportive of values of their family and culture.

G4 Environment: All students value a healthy local and global environment, and they knowingly work to improve the quality of the environment.

Comment: Some of the most successful uses of information technology in schools have centered around environmental projects. Students work on environmental problems in their own communities and/or on a wider scale. For example, students make use of microcomputer-based instrumentation to gather data on water and air quality. Data may be shared from sites throughout the city, state, nation, or world through use of e-mail. It has become common for students to develop hypermedia documents as an aid in disseminating the results of their studies.

G5 Overall Educational System: All communities knowingly work toward having both formal and informal educational systems that work together on the following Achieving Goals.

Comment: Information technology is now well embedded in our communities. The entire community can be a supportive learning environment as students learn about information technology. School-business partnerships for information technology have become common. For example, many companies refurbish the microcomputers that they are replacing, and provide them to schools.

Achieving Goals

- G6 Basic Skills: All students gain a working knowledge of speaking and listening, observing (which includes visual literacy), reading and writing, arithmetic, logic, and storing and retrieving information. All students learn to solve problems, accomplish tasks, deal with novel situations, and carry out other higher-order cognitive activities that make use of these basic skills.

  Comment: Many people now argue that information technology literacy is a basic skill. A number of states have set goals for having all of their students gain basic knowledge and skills in use of a variety of information technology tools.

G7 General Education: All students have appreciation for, knowledge about, and understanding of a number of general areas of education, including:

- Artistic, intellectual, social, and technical accomplishments of humanity.
- Cultures and cultural diversity; religions and religious diversity.
- Governments and governance.
- History and geography.
- Mathematics and science.
- Nature in its diversity and interconnectedness.

Comment: Information technology is part of the technical accomplishments of humanity. The history of information technology is an integral component of the history of the human race.

G8 Lifelong Learning: All students learn how to learn. They have the inquiring attitude and self-confidence that allows them to pursue life's options. They have the knowledge and skills needed to deal effectively with change.

Comment: Information technology will continue to change quite rapidly. It will present a learning challenge to students of all ages throughout their lifetimes.

G9 Problem Solving: All students make use of decision-making and problem-solving skills, including the higher-order skills of analysis, synthesis, and evaluation. All students pose and solve problems, making routine and creative use of their overall knowledge and skills.

Comment: Information technology is a powerful aid to problem solving in every academic discipline. The idea of Person Plus is important throughout all grade levels and subject areas in school.

G10 Productive Citizenship: All students act as informed, productive, and responsible members of organizations to which they give allegiance, and as members of humanity as a whole.

Comment: Information technology, including the World Wide Web, is fast becoming a routine component of life in our society.

G11 Social Skills: All students interact publicly and privately with peers and adults in a socially acceptable and positive fashion.

Comment: Information technology has brought us new forms of communication and social interaction, including desktop conferencing, picture phones, e-mail, and groupware.

G12 Technology: All students have appropriate knowledge and skills for using our rapidly changing Information Age technologies as well as relevant technologies developed in earlier ages.

Comment: Information technology is both a discipline in its own right and a driving force for change in many different areas of technology, science, and research.

Long-Range Strategic Planning

- Many organizations do long-range strategic planning. They decide where they would like to be 5 to 6 years in the future, and then they commit their resources to getting there. That is, strategic planning can be thought of as a combination of predicting the future and of allocating resources to shape the future.

  Strategic planning is a process that leads to a product. The product, a strategic plan, is useful to the extent that:

  - it embodies creative, careful, and realistic thinking;
  - it is implemented in an appropriate and thoughtful manner; and
  - it contributes significantly to accomplishing the mission of the organization.

  Many organizations find that the process of developing a strategic plan contributes as much or more to an organization than does actually having such a plan in hand. However, a strategic plan is very important to have available because it provides a framework for day-to-day and longer-term decision making on the part of the staff and volunteers who work for the organization.

  In general, completion of a long-range strategic plan then leads to the development of a medium-range plan that covers 2 to 3 years, and a short-range plan covering one year. One-year plans are particularly important in education because typically one can accurately forecast the resources (money and people) that will be available during the year.

Once a long-range strategic plan is in place, it needs to be updated each year. This provides a basis for annually updating the medium-range plan and creating the next year's plan. All of this gets tied into the budget cycle, as a year's budget is designed to accomplish specific short-term goals in the year's plan.

Six-Step Strategic Planning Process

- A six-step strategic planning process for technology in education is outlined below. A strategic planning team should include members from the various stakeholder groups that are involved with and/or interested in education. Typically, several members of the team will be community members who are not educators. A small school might require about 100 person-hours of time to complete the process. A large school district might require 1,000 or more person-hours of time to complete the process. Keep in mind that quite a bit of the time is used to help educate the planners. The time and effort invested in this education process is essential to achieving overall success in the strategic planning process.

1. Evaluate the Situation

The starting point for strategic planning is a careful evaluation of the current situation. This step is often called an *environmental scan*. Much of the work needed to complete an environmental scan can be assigned to staff and can be completed before the first meeting of the strategic planning group. However, once the group begins meeting, it will likely generate additional requests for such information.

  - Analyze the environment and the planning assumptions. Identify the key stakeholders, their beliefs and goals, and the current state of affairs.

  - Tabulate such resources as money, personnel, time, and so forth and decide whether these are certain, allocated, or probable. Resources are needed both to carry out the strategic planning process and to implement the plans that are developed.

- Gather and analyze data on what is working well and what is not working well. For example, what are the current uses of technology in the organization, and what are students learning about such technology?

- Gather baseline data that adequately describes the current situation. This will consist of both quantitative and qualitative data. This baseline data is needed both for planning purposes and to measure change over time, as implementation of the strategic plan proceeds over the years. Conclusions from the data can become assumptions for planning.

2. Articulate a Vision

Although long-range strategic planning usually focuses on a 5- to 6-year time span, it is important to have a vision of what might be accomplished over a much longer time span. This vision might be focused 15 or more years in the future.

Imagine a member of the strategic planning committee sharing hopes and fears:

- *My child will enter kindergarten next year. I hope and expect that my child will at least complete two years of technical training in a community college-I think that is going to be essential to get a good job.*

  What will the world be like when my child is finishing school, looking for a job, and taking on more and more adult responsibilities? Will the formal and informal education that we have been able to provide prove adequate?

  I am particularly concerned about how rapidly technology is changing, and how this is changing jobs. I want my child to be ready for the jobs that have not yet even been created. I want my child to have the knowledge, skills, and learning habits that will be needed to deal with the changing job situations 15 or more years from now.

This sort of sharing is a starting point for the strategic planning group forming a vision. Every member of the group can share hopes, fears, and visions. This type of sharing activity is a good way for the planning group members to get to know each other. Notice that it is personal-it does not focus on any particular stakeholder group. It helps to create a shared vision that moves beyond the concerns of any particular stakeholder group.

Such a vision is painted in very broad strokes. Thus, it might focus on the problem solving and learning challenges today's preschoolers will face on the job, as homemakers, and as responsible adults 15 years from now.

3. Decide on a Mission Statement

A strategic planning group needs to decide on a technology in education mission for the school or school district for which the strategic planning is being done.

A mission is an ongoing purpose, the reason an organization exists. It should be simple, direct, and easy for people to understand. Perhaps you remember what the mission of the March of Dimes was a number of years ago. Its mission was to conquer polio. This was a mission many different groups of people supported over many years. Now the organization has a new mission-to conquer birth defects. Notice that both the initial and the current missions of the March of Dimes are simple, direct, and easy to understand.

For a school district, a sample mission statement might be "To ensure that all of our students are technologically literate." Quite likely the term "technologically literate" will be defined as a moving target-that is, a target based on ever changing contemporary standards. Thus, the mission will never be fully accomplished.

4. Propose and Select Goals

The vision must be translated into specific goals and objectives. These need to be grounded in the reality of the resources available to the organization. The research literature on strategic planning suggests that a plan should not contain more than a half-dozen major goals.

Each goal can be supported by several objectives. And, of course, objectives can be supported by subobjectives. However, such detailed levels of goals, objectives, and subobjectives is apt to result in a plan that will not be accomplished. It places far too much emphasis on a top-down approach to problem solving and leaves too little to the insights and initiatives of those people who will actually be implementing the plan.

5. Develop a Strategic Implementation Plan

The strategic planning group needs to develop an overall implementation plan based on the agreed-upon goals and objectives. Who will do what, by when, using what resources? Who will be responsible for monitoring and reporting on progress?

The implementation plan has short-term (perhaps one year or less), medium-term (2 to 3 years), and long-term (4 to 5 years or more) components. Remember that the development of an implementation plan requires careful examination of the goals. Quite likely, goals and objectives will be revised during planning for implementation.

The strategic planning group will probably develop only a rough plan for implementation. Details may best be left up to the school personnel who have the authority and responsibility for implementation. Some planning groups and advisory councils have a tendency to "micromanage"-to attempt to spell out small details of what is to be done to achieve particular goals. This is inappropriate and can seriously hinder schools from actually achieving the goals.

6. Periodic Assessment and Update

Once a plan has been adopted, school personnel will choose, organize, and work on specific activities that are based on the overall implementation plan and that lead to achieving the adopted goals and objectives. They will also set in place an evaluation process that provides information needed by decision makers, implementors, and planners.

Evaluation must be an ongoing part of strategic implementation. A key idea is that results from the evaluation are fed into current planning. Successful planners periodically revise and update the strategic plan based on the ongoing formative evaluation process. The long-range strategic plan should be carefully examined each year and should be updated based on information gathered during the year. Typically, the updating process takes only a small fraction of the time and effort used in the creation of the original plan.

The *National Center for Technology Planning* is a clearinghouse for the exchange of information related to technology planning, including school district technology plans, technology planning aids, sample planning forms, and electronic monographs on related topics. The address is:

Larry Anderson
Drawer NU
Mississippi State, MS 39762
Phone: 601/325-2281
E-mail: LSA1@RA.MSSTATE.EDU
URL: gopher://gopher.msstate.edu:70/11/Online_services/nctp/

A Route to School Improvement and Change

- David Perkins (1992) analyzes the processes of school improvement and change. He gives a set of six criteria-all which need to be met-if a project is to have a positive, long lasting effect on a school. The six criteria are given below, along with some analysis from an information technology point of view. A long-range strategic plan for educational change should pay careful attention to the ideas presented in this section.

    - Do not escalate teacher workload. While information technology can increase productivity, invariably there is an initial phase of use in which decreased productivity occurs. This is part of the learning effort. In education, part of this difficulty can be overcome by providing teachers release time for professional development and by providing them with in-school (indeed, in their classroom) training and technical assistance.

    - Allow teachers a creative role. One key aspect of the Information Age is a restructuring of business that includes considerably increased empowerment of the front line workers. Classroom teachers must be involved in design and implementation of their own professional development as well as in changes in curriculum, instruction, and assessment.

- Avoid extreme demands on teachers' skills and talents. The field of information technology in education is extensive and growing. It takes a great deal of knowledge and skills to function well in this field.

- Include strong materials support. Teachers need good instructional materials, and students need good learning materials, for technology in education.

- Do not boost the school costs per student a lot. At the current time, computer hardware and software are an add-on expense in education. As discussed elsewhere in this book, potential expenses can be considerable. Careful thought needs to be given as to whether the information technology expenses will lead to decreases in other expenses.

- Fulfill many conventional educational objectives at least as well as conventional instruction. Chapter 3 of this book draws a parallel between the three R's and use of information technology in education.

What Will It Cost?

- This book contains forecasts of steadily increasing allocation of K-12 educational resources toward meeting the goals of technology in education. It is clear that it will cost a great deal to achieve those goals. Some of the needed funds can be obtained by reallocation of funds currently being allocated to other purposes. Major additional funding from other sources will likely be necessary.

  At the current time in the United States, perhaps 1.5% of school budgets is being spent on information technology hardware, software, networks, infrastructure, and support systems (U.S. Office of Education, June 1996). Already, however, there are schools that are spending 5% of their budgets in these areas. Over the long run, even this 5% figure will prove to be inadequate.

  To understand why this is so, imagine a school of the future in which every student has routine access to technology-enhanced learning. These TEL resources are available to the student at school and at home. The resources are backed up by a well-maintained infrastructure and support system. Among other things, this support system provides teachers with the inservice education and technical support that they need to continue to grow on the job.

In terms of 1996 dollars, the average cost of public education in the United States is about $6,000 per student per year. Ten percent of this amount is about $600 per student per year. Now, imagine how far $600 per student per year will go in terms of:

1. Providing every student and teacher with a powerful portable computer and a full range of computer productivity tools.

2. Providing every classroom with a technology infrastructure that includes scanners, printers, camcorders, desktop presentation, and network connections.

3. Providing every student and teacher good access to the full range of TEL facilities both in and outside of school.

4. Providing maintenance and repair staff, as well as other technical support.

5. Providing continuing inservice education and support for teachers.

6. Providing ongoing curriculum revision and curriculum development to keep pace with the continued change in the technology.

Even 10% of the school budget is not enough to provide all of these facilities and services. Thus, over the next decade we will see a steady rise in the average percentage of the K-12 educational budget that is going into technology. Ten years from now we will see a number of schools spending well over 10% of their budgets for such technology.

The work of Henry Becker suggests that 10% is far too low an estimate of the needed resources. In Becker's (Fall 1993) article "A Truly Empowering Technology-Rich Education-How Much Will It Cost?" in the *Educational IRM Quarterly*, he analyzes technology costs based on schools that are making exemplary use of computers. He breaks the costs into facilities (such as items 1-3 in the list given above) and staff (such as 4-6 above). His conclusion is that the staff costs will exceed the facilities costs. This is consistent with a rule of thumb from the business world that hardware, software, and other related infrastructure make up about half the costs of providing employees with computer facilities.

Becker suggests that for an average school to have reasonably up-to-date computer facilities and a good support system might well cost 30% of the current school budget. He compares this with the costs of implementing other types of major changes to the school, such as costs of implementing Ted Sizer's Coalition for Essential Schools model for secondary school organization and instruction. The costs were not a great deal different from what Becker feels would be necessary to support exemplary use of information technology.

Notice the huge discrepancy between what Henry Becker is predicting for the eventual costs of information technology in education, and David Perkin's suggestion that to have a good chance of success, educational changes should not cost too much. This huge discrepancy suggests that full integration of information technology into our educational system faces a very difficult path.

How Long Will It Take to Get There?

- Few writers seem to be willing to make predictions about how long it will take to thoroughly integrate information technology into our educational system. Will we be there 50 years from now? A major part of the difficulty is that we face a moving target. Information technology is changing quite rapidly, so it is not at all clear what one might mean by "thoroughly integrate information technology into our educational system." It seems safe to say that this integration will not occur during the next few decades. That is, the pace of change of information technology will far exceed the pace of change in schools attempting to adjust to information technology.

Think back to earlier in this book where we were talking about the impact of steam power and the Industrial revolution in England. Fifty years into the Industrial

Revolution, the economy of the country had been transformed by steam power. However, electrical power, the internal combustion engine, and the jet engine had yet to be invented. The Industrial Revolution was still in its infancy. A number of technological breakthroughs would occur during the next hundred years, but these were not evident to people at that time.

It is highly likely that the same situation exists for the Information Age. For an example, consider the field of Artificial Intelligence. Alan Turing, a pioneer in the development of computers, provides us with a 50-year historical perspective. Alan Turing helped to develop the first electronic digital computers built in England during the early 1940s. He was a brilliant mathematician and an early contributor to the research in computer and information science. In 1950 he posed a test for Artificial Intelligence. The test is an imitation game, and has come to be called the Turing Test. The idea is to develop a computer program that interacts with a human via computer terminal, and that can consistently fool the human into believing that he/she is interacting with a human being. Turing predicted that within 50 years, by the year 2000, the computer field would have achieved such progress. He made this prediction at a time when there were only about 20 computers in the whole world and the first commercially-produced computer had not yet rolled off the assembly line.

Today's fastest computers are far more than a million times as fast as the computers in 1950. An immense amount of progress has occurred in programming and in Artificial Intelligence. Many people and groups have attempted to develop computer programs that will pass the Turing Test. Indeed, there is a substantial prize being offered to the first person/group to achieve this feat. So far-no winners.

Will the next 50 years bring us walking, talking robots that readily pass the Turing test? Will these robots have human-like intelligence, be multilingual, and be able to carry on a learned conversation about any topic that happens to interest a human conversationalist? Will such robots surpass humans in their problem solving and research skills?

Will the next 50 years bring direct neural connections between human brains and powerful computers? For example, will part of the education of a child include brain implants of computer memory chips and processing chips? What would it be like to have one's brain augmented by a few billion bytes of factual information and a high speed processor?

Clearly, the previous two paragraphs are currently just science fiction. Will this type of science fiction become factual in 50 years? A hundred years? A thousand years? Never?

We are approximately 50 years into the Information Age. The next 50 years will bring many times the changes we have seen in the past 50 years. While some of these changes will be orderly progressions from current technology, others will be major and unforeseen breakthroughs. Some of the ideas that we now think of as science fiction will become factual.

Conclusions and Recommendation

- We are at the very beginning of a major change in education. While the basic goals of education will not change much during the next few decades, our methods of working to achieve these goals will change substantially. There will be a major restructuring of educational funding in order to support putting 10-20% or more of school budgets into information technology.

  Impetus for change can come from any stakeholder interested in education. A small number of determined parents, for example, can cause major changes in a school system. However, a larger and more broadly representative group is usually more effective. If you are working to increase the use of information technology in a school or school district, you may want to form a team that has the same types of representation that are needed for long-range strategic planning for information technology.

  Long-range strategic planning provides tools for examining possible changes and systematically addressing the change process. While many schools have a long-range strategic plan for information technology, most such plans are woefully inadequate. Almost every school and school district can benefit by developing and implementing a more careful and ongoing approach to long-range strategic planning for information technology.

<<< Chapter 8 Contents References >>>

Return to Cover Page

<<< Chapter 9 Contents

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The key idea in *PowerShift* is that knowledge is power (knowledge is a resource) and that this form of power is rapidly changing the world. The book explores other forms of power (other resources), such as agricultural productivity as power, industrial manufacturing capacity as power, and violence (military might) as power. Various countries are analyzed on the basis of the balance that they have in these different forms of power.

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