

Planning, Forecasting, and Inventing Your Computers-in-Education Future

Don't worry about what anybody else is going to do. ...
The best way to predict the future is to invent it. (Alan Kay)

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The first edition of this book was published on January 31, 2004. In this second edition, all of the references have been brought up to date and a number of references have been added. Many small corrections have been made. A modest amount of material has been deleted and/or replaced by more recent material, and about eight pages of other new materials have been added.

Preface

Great deeds are usually wrought at great risks. (Herodotus, fifth century BCE)

When you are up to your neck in alligators, it's hard to remember the original objective was to drain the swamp. (Adage, unattributed)

It would be a “great deed” to substantially improve our educational system. I strongly believe that our education system can be a lot better than it currently is. Indeed, I predict that during the next two decades we will substantially improve our educational system. In this book, I enlist your help in making this prediction come true.

The focus in this book is on two aspects of improving our educational system:

1. Improving the quality of education that K-12 students are receiving.
2. Improving the professional lives of teachers and other educators.

This book is mainly designed for preservice and inservice teachers and other educators. If you fall into this category, you will find that this book focuses on your possible futures of Information and Communication Technology (ICT) in education. It will do this by:

- Helping you make and implement some ICT-related decisions that will likely prove very important to you during your professional career in education.
- Helping you to increase your productivity and effectiveness as you work to improve the quality of education being received by your students.

A second audience for this book is individuals and stakeholder groups that represent schools, school districts, and other educational organizations. This book is designed to help such audiences carry out long-range strategic planning for ICT in their organizations. The goal is to help improve the productivity and effectiveness of our education system as it works to improve the quality of education of the students it serves.

Formal school-based educational systems have existed for more than 5,000 years (Vajda, 2001). During this time, the goals of education have changed to meet the changing needs of our societies. Many of the changes have been driven by changes in technology and science. Some have been developed by educational practitioners, while others have been developed by educational researchers.

Here are two models of educational change:

1. Continuous improvement model of small, incremental changes. All teachers are familiar with this, as they continually learn on the job and try new things to better meet the needs of their students.
2. Paradigm shift model of discontinuous jumps. The invention of reading and writing, and later the mass production of books, were each paradigm shifts that greatly changed education (Printing Press, n.d.). In this book, we will examine some possible ICT-based paradigm shifts in education.

You know that at the current time science and technology are progressing at an unprecedented pace. Information and Communication Technology is one of the most rapidly changing areas of technology. Over the past several decades, capabilities of ICT hardware systems (computer speed, primary memory size, storage capacity, bandwidth) have been doubling every 1.5 to 2 years. Current estimates are that this rapid pace of change may well continue for another 10 to 15 years or so. (Remember, a doubling in two years means as much additional change as in all previous years put together. Five doublings is a factor of 32.)

Notice how we have “slipped in” a forecast or prediction for the future. Suppose that this forecast proves to be accurate. Then today’s toddlers will reach adulthood in a world where ICT systems are perhaps 100 to 1,000 times as powerful as they are today. What might this suggest we should be doing during the years of formal education these students will be receiving? Will schools be the same 15 to 20 years from now as they are now?

It is easy to make forecasts or predictions about the future. However, it is not so easy to make predictions that are backed by careful analysis of current situations, trends, an understanding of change processes, and so on.

Here is a 1997 quote from Peter Drucker, one of the leading gurus of business management during the past half century:

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 10 Mar 97).

Notice the 1997 date on this prediction. If you have been paying attention to higher education in the past eight years, you will have seen a number of things going on that are consistent with this forecast. The most obvious change that is going on is Distance Learning, with more and more higher education and precollege learning opportunities being made available through this environment. But there are other important changes going on, such as higher education students now making more use of the Web than “traditional” libraries as an information source, and most college students both owning and regularly using a microcomputer. In addition, most institutions of higher education are facing steadily growing financial problems and there is steadily growing competition for students and grant funding.

What do you think might happen in precollege education during the next couple of decades? ICT has proven to be an aid to solving problems in every academic discipline. It is obvious that ICT is a powerful aid to helping to accomplish a wide range of educational goals. Moreover, ICT has created new challenges or goals in our educational system, such as that of providing students with appropriate education in this new field.

Whether you like it or not, your professional career in education is being affected by ICT, and the affect will grow over time. You can view the rapid growth in the education-related capabilities of ICT as providing you with both major challenges and major opportunities. In either case, you can think about doing some planning for what now exists and what will exist.

This book is about forecasting and inventing *your* personal future in the field of Computers and Information Technology (ICT) in PreK-12 education and in teacher education. In this book, the word “your” covers the reader and any organization that the reader happens to be involved

with. This book will help you to plan for some of the ICT aspects of your future as a professional educator.

David Moursund

June 2005

Chapter 1

An Invitation

Men occasionally stumble over the truth, but most of them pick themselves up and hurry off as if nothing ever happened. (Sir Winston Churchill)

The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom. (Isaac Asimov, Isaac Asimov's Book of Science and Nature Quotations, 1988)

The quote from Winston Churchill represents how many educators have been dealing with the field of Information and Communication Technology (ICT) in education. I am deeply disturbed by this situation. I invite you and your colleagues to learn more about “the truth” of ICT in education, and to incorporate this truth into your careers as professional educators.

This chapter provides a little historical background. It paints a picture of waves of change that play out over many hundreds or even thousands of years. You just happen to have been born during the early phases of such a wave of change—the Information Age.

This short book is for preservice and inservice teachers. I invite you to think about the future of your students and how you will contribute to their future. I invite you to think about your future roles in the field of ICT in education. This book will help you to become a better teacher, better able to meet the rapidly changing needs of students growing up in our rapidly changing and increasingly technological society.

If you skipped over the Preface, I recommend you go back and read it. It is an integral component of the content of this book. Pay special attention to the continuous improvement model and the paradigm ship model of educational change.

Brief History of Formal Education (Schooling)

The overriding goal of this futures-oriented book is to help improve our educational system. Formal education (schooling) for many students nowadays begins when they are about five years old, and it may continue through high school and beyond. However, it is only necessary to step back about 250 years to reach a time when most of the world’s population was illiterate and innumerate. Even today, many tens of millions of the world’s children do not progress beyond the fifth grade in their formal education.

We humans are called *Homo sapiens*, and we have lived on this planet for perhaps 175,000 to 200,000 years. For many tens of thousands of years we were hunter-gathers, living in small tribes. There were few changes in this life style from generation to generation, or even over thousands of years. There was a very slow pace of accumulation of new knowledge and of sharing this knowledge among the population. The worldwide population was small. It is estimated that the total human population of the earth was probably fewer than 12 million people just before the start of the agricultural age, some 11,000 years ago.

Agricultural Age

The beginnings of the agricultural age were also the beginnings of a significant increase in the pace of change in the societies of the world. This was a major paradigm shift in how people obtained their food. Agriculture brought a type of stability that permitted the growth of villages,

and then towns, and then cities. It permitted increased specialization of work activities, and it fostered an increasing accumulation and sharing of knowledge.

By a little more than 5,000 years ago in Sumer (a country located in the area now called Iraq) the growth of population and accumulated knowledge was overwhelming the bureaucratic and business record keeping systems of the time. This led the Sumerians to develop the three Rs—reading, writing, and arithmetic (Vajda, 2001).

Reading, writing, and arithmetic are powerful aids to the human mind. They are a powerful aid to accumulating and disseminating knowledge, and they are a powerful aid to solving complex problems and accomplishing complex tasks. Indeed, the three Rs are so important that they still remain at the core of formal education systems. The development and eventual widespread use of the three Rs was a major paradigm shift.

Moreover, we are all aware of the power of reading and writing. In 1041, movable clay type was first invented in China. Johannes Gutenberg invented a printing press with movable wooden or metal letters in 1436-1440 (Bellis, n.d.). The subsequent mass production and mass distribution of books in the Western world contributed substantially to changes throughout the world. Movable type printing was a major paradigm shift.

While the development of the three Rs and a formal educational system speeded up the pace of accumulation of knowledge, the commutative effect on most people was still modest from generation to generation. Even as recently as 250 years ago, most people worked on farms and experienced paradigm shift changes throughout their lifetimes. Most people received very little or no formal schooling.

For example, at the time of the Revolutionary War in the part of the world that is now the United States, more than 90 percent of the population lived on farms. Thomas Jefferson was one of the writers of the 1776 Declaration of Independence and the Constitution of the United States, and he was the third president of the US. At one time he proposed to the Virginia Legislature that free public education up through the third grade should be made available to all Virginian citizens. (Slaves were not considered citizens). This was such a “far out” idea that it was not adopted.

That is not to say that there were no changes over these thousands of years. However, for most people the pace of change was relatively slow—it was not overwhelming or discombobulating.

Industrial Age

Then came the industrial revolution, beginning first in Great Britain. The following is quoted from the October 1845 issue of *Scientific American*:

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.

The Industrial Revolution—fueled by steam power—began in Great Britain in the late 1700s. The quote indicated that 50 years into this Industrial Revolution, the installed base of steam power in Great Britain 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 horsepower per person. That is, one horsepower is about the same as five or six "person power." (Think about that statistic the next time you push down the gas pedal on the 200 horsepower gasoline engine in a car!)

The pace of change in accumulation and dissemination of human knowledge continued to quicken. In Great Britain, the huge influx of workers, moving from farms to work in city factories led to the development of some limited forms of child labor laws and the development of wide scale public education. These early public schools were a major paradigm shift, and they designed to keep children out of the factories and off the streets—to keep them occupied in a gainful manner. The school environment tended to be factory-like, and such factory-like schooling is still common today in many parts of the world.

Information Age

In the mid 1950s in the United States, the number of white-collar jobs first exceeded the number of blue-collar jobs. This marks the official beginnings of the Information Age. Now, about 50 years later, less than 3% of the US workforce is classified as agricultural, and only about 15% is classified as industrial manufacturing. The pace of change in science and technology has quickened. We are seeing huge changes during a person's lifetime.

I was born before the beginning of the Information Age. During my lifetime I have seen the development of nuclear weapons and nuclear power. I have seen the discovery of the double helix model of DNA. I have seen huge progress in medicine. I have seen the human genome project. I have seen the development of space flight, with people landing on the moon and the various Mars rover projects. I have seen the development of cloning. I have seen the development of the electronic digital computers and the field of Information and Communication Technology. I have seen the development of nanotechnology. I have seen the development of communication satellites, fiber optics, and cell telephones. I have seen the development of brain scanning equipment and rapid increases in accumulated knowledge in the Science of Teaching and Learning.

Moreover, I have seen the pace of science and technology “progress” continue to increase. Think about this in terms of your work as a current or future teacher. During the lifetime of your students, the world will likely see a factor of more than 100 in the total accumulation of human knowledge. This is a conservative estimate, based on an estimated doubling every ten years. Seven such doublings over a span of 70 years produces a factor of 128 in the annual growth rate. A University of California report suggests that the totality of stored information is growing at 30% a year (How Much Information, 2003). However, such a finding does not really address the issue of how much new knowledge is created and stored per year.

Many people have trouble comprehending the meaning of a doubling of the power of an ICT system or a doubling of the total accumulated knowledge. In terms of ICT systems, the doubling which is now occurring in a period of 1.5 to 2 years means that the change during 1.5 to 2 years is equality to all of the change that has occurred in all of the years before than. Consider a student entering college as a freshman, and planning a five-year program of study leading to becoming a fully certified teacher. During this five-year period of time, the capabilities of a microcomputer system might increase by a factor of eight, which is the result of three doublings.

Or, consider a toddler now, and the toddler completing college perhaps 20 years from now. During this time, the totality of human knowledge may quadruple (two doublings). Such forecasts certainly point to the futility of basing an education system mainly on rote memory!

Concluding Remarks

Clearly, our formal educational system must help each student learn to cope with immense changes in technology and science that will occur during his or her lifetime. A factory-oriented

model of education with its emphasis on rote memory and “pouring” the same knowledge into each student’s head no longer suffices. Schools are now beginning to place more emphasis on:

- understanding (as contrasted with rote memorization), higher-order cognition, and problem solving; and
- helping each student learn to learn and learn to be a lifelong learner.

Information and Communication Technology is but one aspect of the future of technology and science. There are many other technologies in addition to ICT, and there are many other sciences besides computer and information science. Appendix A, *Technology*, provides a brief overview of broader aspects of technology.

ICT is but one aspect of the challenges facing our educational system. It is but one aspect of the challenges you face in being a good teacher. However, ICT is a central (core) challenge, especially in education. The next two decades will likely see changes by a factor of 1,000 or more in the speed of computers, storage capacity of computers, and telecommunication bandwidths. Software will continue to make significant progress. ICT systems will become more and more “intelligent,” and they will steadily become more powerful aids to human intellectual performance. In many ways, the potential impacts of ICT on education are mind-boggling. If you are ready to have your mind boggled, read on!

Personal Growth Reflections and Conversations for Chapter 1

Each chapter of this document contains one or more suggestions for reflection and possible conversations based on the ideas covered up to this point in the book. The intent is to get you actively engaged in learning and using the materials that you are reading.

1. Think back over your formal K-12 schooling and the emerging scientific and technological changes that occurred the first 18 years of your life. Reflect on how well your formal schooling introduced you to these changes and prepared you for a still greater pace of change that is currently going on. Talk to some of your fellow preservice or inservice teachers about this situation.
2. Name some pieces of technology that you currently routinely use, but that did not exist when your grandparents were your current age. In what sense did these pieces of technology produce a paradigm shift? Reflect on what kind of education might have helped your grandparents cope with such changes.

Activities for Chapter 1

Activities are for use in workshops and small group discussions, and for use as written assignments in courses. In almost all cases, the Activities focus on higher-order “critical thinking” ideas.

1. More than 2,000 years ago, The Library of Alexandria was by far the greatest library of its time. It contained the equivalent of perhaps 40 to 50 thousand books. Use the Web to do research on how this compares to the current US Library of Congress.
2. The Web is an online library. On 12/27/03, the Google search engine Website indicated that Google was searching 3,307,998,701 Web pages. On 5/17/05, Google was searching 8,058,044,651 Web pages. Is the Web now “bigger” than the world’s largest “physical” library, the U.S. Library of Congress? See if you can find data that helps you to compare the current amount of material searched by Google to the size of the US Library of Congress.

3. The totality of human knowledge is already many millions of times as much as a person can memorize, and it is continuing to grow very rapidly. What types of things can a student learn in school that will have continuing value throughout his or her lifetime? Analyze how some of your answers fit in with the current design of school curriculum, instruction, and assessment.

Chapter 2: Inventing the Future

Any science or technology which is sufficiently advanced is indistinguishable from magic. (Arthur C. Clarke.)

Any technology that is distinguishable from magic is not sufficiently advanced. (Gregory Benford.)

The “indistinguishable from magic” quote from Arthur C. Clarke is one of my favorites. Science fiction was an important part of my childhood, and it has been an important part of my adulthood. It has been fun to be alive during a time when many of the magical ideas from science fiction have become the reality of our everyday world. Many of the things that you take for granted would certainly have seemed like magic to the people of 200 years ago. (When you read the previous sentence, my hope is that you will also think about people of 200 years from now looking back at the present.)

The Web is now about 15 years old. It provides an excellent example of one person—Tim Berners-Lee—inventing the future. Now, Berners-Lee and others are inventing a smarter Web, called the Semantic Web (Vaas, 2004).

From my point of view, one of the pieces of magic that has seemed to be far in the future is thin, flexible (so you can roll it up) computer display screen. However, these are now commercially available. Indeed, a display screen can be “printed” on a shirt or other article of clothing (Flexible Displays, 2004).

Aids to Human Physical and Mental Performance

It is easy to think of tools that provide aids to human **physical performance**. Examples from tens of thousands of years ago include the stone ax, spear, and flint knife. Examples from thousands of years ago include tools to aid farmers and carpenters. Nowadays, such tools include cars, trains, and airplanes.

Reading, writing, and arithmetic provide examples of human-developed aids that augment and enhance human **mental performance**. By this I mean that a person who has learned to make effective use of the three Rs can far outperform a person who lacks these skills in many mental activity areas.

Here are four important ideas about tools:

1. Although it may take uncommon knowledge, talent, and skills to develop a new tool, more ordinary people may well be able to learn to produce and use the new tool. (It may take an “Einstein” to develop a new physical or mental tool, but it does not take an Einstein to learn to use such a tool once it has been invented.)
2. The amount of time and effort—and the amount of informal and formal training and education—needed to learn to make effective use of a tool varies tremendously both with the learner and the tool.
3. Tools change tool users and the societies in which they live.

4. One of the major goals in education is to help students achieve a relatively high level of expertise in a variety of areas deemed important by society. As students increase their levels of expertise in a discipline, they learn to more effectively use the physical and mental tools that are appropriate to the discipline. Some of these tools are quite specific to a particular discipline, while others are useful over a wide range of disciplines. Since the three Rs are useful across so many different disciplines, they are considered part of the core of education and our schools work to help all students gain a functional level of expertise in these areas.

Information and Communication Technology (ICT)

ICT includes a wide range of computer and telecommunications hardware and software, and supportive knowledge and ideas. The computer hardware ranges from the processing and memory chips embedded in appliance controllers and wrist watches, to palmtop computers, to laptop and desktop microcomputers, to mainframe computers, to supercomputers to quantum computers. Connectivity includes a wide range of wireless approaches and satellites, and a wide range of hard-wired approaches. ICT includes the Internet, which in turn includes the Web. ICT includes digital cameras and digital video. It includes the fields of Computer and Information Science, and Computer Engineering. To summarize, we do not want to be overly restrictive as we consider possible futures of ICT in education.

ICT is an aid to enhancing, augmenting, and helping to automate human performance of both physical tasks and mental tasks. Figure 2.1 illustrates this idea in terms of problem solving and task accomplishing. In this diagram, the “team” can be thought of as one or more people.

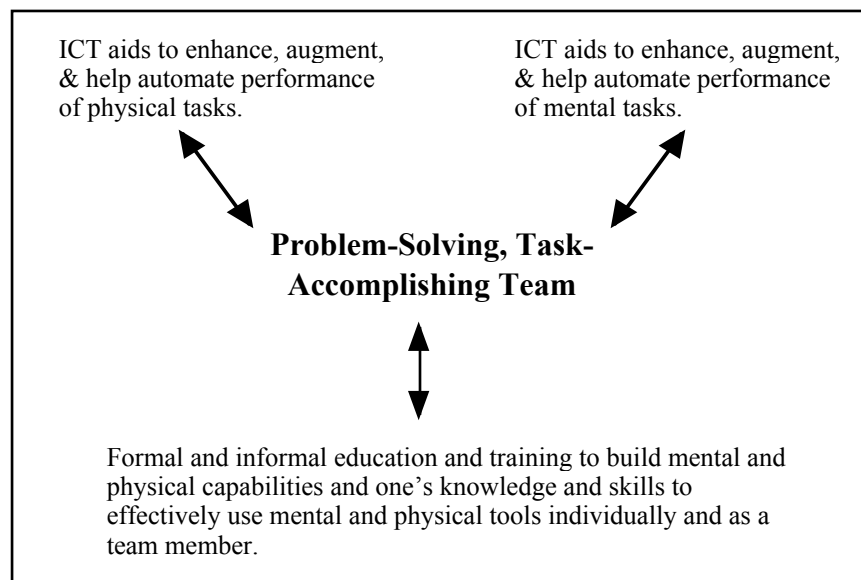


Figure 2.1. ICT aids to accomplishing physical and mental tasks.

Cars and airplanes provide good examples of the partial automation of a physical task—the task of moving oneself and others from place to place. Today’s cars and airplanes contain a number of ICT systems that automate a variety of functions. At the current time, a driver still drives the car. However, many airplanes contain automatic pilots that have great skill in piloting an airplane. Moreover, the US military now has a pilotless surveillance airplane that can take

off, fly thousand of miles to a target area, spend many hours videoing the area and sending the videos to an orbiting satellite, return to home base and land—all without human intervention.

A four-function calculator can be thought of as a mental aid that automates the processes of addition, subtraction, multiplication, and division. A computer program that plays chess can be thought of as an ICT system that automates solving the problem of making chess moves. Nowadays, chess playing programs that run on a microcomputer can defeat most human chess players.

It is easy to forecast that the future will bring us more aids to the performance of physical and mental tasks. More powerful ICT systems and more progress in artificial intelligence research will bring us “smarter, more intelligent” aids to solving problems and accomplishing tasks (Moursund, 2005). The much greater challenge is to develop and implement an educational system that is appropriate to students growing up in a world of rapidly improving aids to solving problems and accomplishing tasks.

Inventing Your Future

Alan Kay has made immense contributions to the field of ICT during his long career. For example, his pioneering ideas of a Dynabook are now reflected in today’s laptop computers. In 1971 Alan Kay said:

Don't worry about what anybody else is going to do. ... The best way to predict the future is to invent it. Really smart people with reasonable funding can do just about anything that doesn't violate too many of Newton's Laws (Rheingold, 1985, Chapter 11).

The title and overall design of the book you are now reading are based on the following multi-step process for “inventing” your future.

1. Gain an increased understanding of the current field of ICT in education and likely futures of ICT in education.
2. Gain an increased understanding of your current roles in ICT in education.
3. Decide on what you would like your future ICT in education roles to be. “Dream,” but temper your dreams with reality. We can’t all be Bill Gates! Most of use will remain dependent on the technology and technological products that are invented and produced by others.
4. Develop a Long-Range Strategic Plan (LRSP) for achieving your desired future roles.
5. Begin implementing your LRSP and monitor your progress toward achieving the future you want to achieve. If you not satisfied with how the future is unfolding for you, return to one of the earlier steps listed above.

There is nothing magical about this invention process. You have a great deal of control over how you use your time, energy, current knowledge and skills, financial resources, and other personal resources. You may well have access to resources that can be loaned to you or provided to you free by others. You can use your personal and other resources to make changes in your life. By doing so, you are changing (inventing) your future. If you have clear future goals in mind, you can use your personal and other resources to move toward achieving these goals.

Being an Inventor

Each of us is highly creative inventor. On a day-to-day basis we figure out (create, invent) ways to solve the problems and accomplish the tasks that we encounter and have not previously

encountered and/or mastered. That is, we invent within the framework of our everyday activities, and we use our personal resources to implement our inventions.

We continually check the results of our actions against the results we expect and/or would like to achieve. If our invented use of our personal resources does not achieve the results we want to achieve, we try some other approach (invent a new plan of action).

The essence of being an inventor consists of four steps:

1. Determining differences between the way things are and the way you would like them to be.
2. Developing (figuring out, inventing) plans and aids to improve or correct the situation.
3. Implementing your plans. (This may involve “building a better mousetrap,” but most often it just requires effective use of the resources you and others already have available.)
4. Monitoring progress toward achieving your goals. If the progress is not satisfactory, return to an earlier step, such as step 1.

Some of us are far more inventive than others, and are more able to develop inventions that lead to major changes in our world. Thomas Edison was one of the world’s greatest inventors. The following quotation, however, suggests that there may be a huge gap between an invention and widespread adoption of the invention to help create a particular future or solve a particular problem.

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.)

This forecast by Thomas Edison underlies a key idea in this book. Thomas Edison invented a number of products. In some cases he started companies to produce and sell his products. The combination of invention, production, marketing, and sales changed the world. Certainly the motion picture was a major paradigm shift!

Now, consider what went wrong with his forecast on the use of motion picture in education. Thomas Edison knew little about formal schools—he was almost entirely home schooled—and he knew little about change processes in education. He thought of education as an information delivery system. (That is, he thought that information delivery was the main paradigm driving education.) He thought movies could replace books, because he thought that movies are a much better than books for delivering information. He was wrong.

Years later, as television became available, people thought that television would replace books and teachers. They were wrong. First movies, and later TV, have been widely used in education. However, they have not proven to be an adequate or appropriate replacement for books and teachers.

Many thousands of research papers have been written on the development and adoption of innovations. Everett Rogers (1995) summarizes the research literature on the adoption of innovations. He points out that many excellent innovations are not widely adopted (Moursund, October 1998).

Everett Roger’s message is quite important. Later in this book, I will propose some significant ICT-based changes in education. These, if widely adopted, would constitute a major paradigm shift. Clayton Christensen has written a book titled the Innovator’s Dilemma: When new Technology Causes Great Firms to Fail (Christensen, 1997). This book explores a number of examples in which major companies were faced by potential paradigm shifts in some of their

products, failed to make the shifts, and eventually went out of business. Moursund (2001) analyzes these ideas in terms of our educational system. Our educational system is struggling with some possible major paradigm shifts that are discussed in chapters 7 and 8 of this book.

As you work to invent your ICT in education future in your classroom or school, **be realistic**. There are powerful reasons why our current education system is the way it is. Our educational system is highly resistant to change. You, personally, can make substantial changes in your own, individual classroom. This is somewhat akin to inventing, producing, and selling a product to a very limited set of consumers. However, even there you may face substantial resistance from your students, their parents, your fellow teachers, and the overall educational system.

As groups of people work together, they have more resources to invent, produce, and sell their collective ideas on some particular aspects of the future. Thus, individual teachers and school administrators can work to invent the futures that they feel are appropriate for a good educational system. Moreover, there is a greater likelihood of success if the great majority of the teachers and administrators in a school decide to work together toward inventing an agreed upon future. There may be still greater likelihood of success if the great majority of the teachers, school administrators, students, parents, schools, school district administrators, school board members, and other key stakeholders in a school district pool their resources to invent a mutually satisfying future.

This section with a quote from Steve Jobs. The quote and the subsequent work of Apple Computer Corporation provide an excellent example of inventing the future.

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. (Steve Jobs, Wired Feb 96 p102.)

In 1984, Apple brought to market the Macintosh computer with its graphical user interface. Steve Jobs and Apple did not invent the graphical user interface. However, Steve Jobs and Apple played a major role in creating our current world of microcomputers in which graphical user interfaces are ubiquitous.

Concluding Remarks

As you continue to read this book, pause from time to time to reflect about the key idea (see Figure 2.1) of automation. You, your parents, and your grandparents grew up in a world where mass production of physical goods was being increasingly aided by automated machinery. When a person grows up in an environment—such as an environment of partially or fully automated factories—the person typically just accepts this situation as the way things are. At some “gut level” you understand and accept factory automation.

You are now living at a time where ICT is brings us more and more information processing (mental) automation. That is, more and more tasks that used to be done using one's mind and simple tools such as pencil and paper are now being done by ICT systems. While some of this automation of mental tasks existed while you were growing up, much of it did not. You are faced by very rapid change in mental automation.

Because of the rapid pace of change of ICT aids to accomplishing mental tasks, your students face some of the same difficulties that you face. While they are growing up in an ICT

environment that is quite different than what you grew up in, they also will face an adulthood in which the continuing changes seem mind-boggling.

This suggests a forecast for the future of education. I predict that our educational system will significantly increase its emphasis on preparing students for change. When I make such a prediction, part of what I am doing is trying to invent a future in which this prediction proves to be correct. By writing this book, I hope to enlist the aid of my readers in helping this prediction to be correct. That is, in writing this book, I am trying to invent the future!

Personal Growth Reflections and Conversations for Chapter 2

1. Think about Alan Kay's statement about inventing the future and the idea that you can invent parts of your future. Envision part of the future that you are trying to invent for yourself, and what you are doing to have this future come true. After you clarify these ideas in your mind, try out your thinking in conversations with some of your colleagues and/or students. Your goal is to develop your own personal understanding of the nature and extent to which people invent their own futures.
2. Think about the idea of automation of mental tasks. What are some examples of mental tasks that you routinely do? Can some of these tasks be automated or partially automated? (By the way, what time is it, what day of the week is it, and what day of the month is it? ... Did you look at your watch to see what time it says, and perhaps to also see what day of the week and month it says? What did people do before the invention of watches and the invention of calendar watches?)

Activities for Chapter 2

1. It is often asserted that our formal education system is very slow to change. For example, perhaps you have heard people jokingly say such things as: "The biggest change in the last 75 years has been unbolting the chairs from the floor, and that change is not yet complete." "The biggest change in the past 75 years has been the introduction of the overhead projector and the white board in place of the chalk board." "Now the books have colored pictures—big deal!" "Now students watch television on small screens, while before they watched movies on a large screen. I wonder if that is a change for the better?" Think about some of the educational changes over the past 75 years. Which of these seem to you to have been major paradigm shifts that have significantly improved education?
2. Why have programmed texts, audiotapes, movies, and television failed to significantly reduce the number of teachers needed in our formal educational system? Based on your current knowledge of computer-assisted learning (CAL), what reason is there to believe that multimedia CAL will prove to be a significantly better aid to independent study and learning than programmed texts, audiotapes, video tapes, and so on.
3. The "No Child Left Behind" legislation of 2001 (signed into law in January 2002) has a strong focus on research-based improvements to education (NCLB, n.d.). Name two or more educational research results from the past 50 years that have made a significant difference in the quality of education that students are currently receiving. Quite likely, you will want to make use of research literature to back up your assertions.
4. An ICT system that contains a computer with word processing software and a printer can be thought of as an aid to one's physical and mental capabilities. Analyze such an ICT

system from the point of view of how it helps to automate certain physical activities and how it helps to automate certain mental activities.

Chapter 3: Some General Background Information

Technology... is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other. (C.P. Snow, New York Times, 15 March 1971.)

We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. (Carl Sagan)

All readers of this book know a great deal about education. After all, how can one help but learn a great deal about curriculum, instruction, and assessment through being a student for so many years?

However, the school experience is not the same for all students, and what students learn about education is not the same for all students. The purpose of this chapter is to provide a summary overview of a few key ideas of education. This will help consolidate some of your knowledge and provide you with some background that is assumed in subsequent chapters.

In addition, this chapter contains a short introduction to Brain/Mind Science. This discipline is of steadily increasing importance in education.

Brain/Mind Science

Your brain is an organ; you have many other organs such a heart, lungs, and skin. You can think of your mind as a product of your brain. From a simplistic point of view, biologists and neurosurgeons study the brain, and psychologists study the mind.

However, in the past couple of decades it has been generally agreed that brain and mind are one. Cognitive neuroscientists study the brain/mind. The cognitive neuroscience discipline has a long history, certainly going back well before the development of the first IQ test in the early 1900s. The past 25 years has seen the development of a number of different non-invasive brain scanning technologies. These make it possible to study which parts of the brain are active when the brain/mind is thinking about and working on various tasks.

Researchers using brain scanning technology have begun to understand how the brain of a dyslexic student is different from that of a non-dyslexic student. Researchers now understand the plasticity of the brain and how the brain physically changes during learning. Such insights have supported the development of computer software that is helping to address dyslexia, ADHD, some problem of severe speech delay, and other problems some students face. Moreover, experiments are now going on with direct neural implants that allow a paraplegic to control a computer just by thinking (Brownlee, 2005).

In some sense, a computer can be thought of as an auxiliary brain, or as a brain supplement. If this topic interests you, read more about it in my book on Artificial Intelligence. (Moursund, 2005). This book is available free on the Web.

To Improve Education

People who talk about improving education tend to talk about two different things. First, they talk about the current goals of education and how to better accomplish these goals. For example, they note that helping students learn to read is a goal, and they are unhappy that some students don't learn to read very well. The underlying assumption is that all students can learn to read well, if we would just do a better job of teaching them, if they would just "try harder," if their parents had just read to them more when the students were very young, if we just had smaller

classes, if there just were not so much competition from television and computer games, and so on. Notice that this list contains a number of things that schools don't have control over.

The other thing they talk about is the goals themselves. Should some new goals be added, and should some of the current goals be deleted or reduced in importance? For example, should our educational system include a goal that all students should learn to play a musical instrument? Should our educational system begin to gradually phase out cursive handwriting, while placing greater emphasis on students learning to print and students learning to use a word processor?

In summary, we can improve education by an appropriate combination of:

- Better accomplishing the current goals of education.
- Investing substantially and wisely into research education and its supporting disciplines, such as Brain/Mind Science.
- Based upon our steadily growing knowledge about the theory and practice of education, modifying, adding to, and/or deleting some of the current goals.
- Major paradigm shifts that allow us to approach old and possible new goals in a significantly different manner that has the possibility of far exceeding what we have accomplished in the past.

Think about the problem of accomplishing the current goals of education. This is not the type of problem that has "a" solution. Rather, it is the type of problem that can be approached from many directions and that allow of incremental progress. ICT provides a variety of aids to making progress in improving how well we accomplish the current goals of education. Because of this, many people forecast that in the future ICT will play a significantly greater role in education.

However, ICT also contributes to establishing new goals and perhaps deleting or significantly modifying existing goals. For example, many schools no longer have a goal of teaching students to use a card catalog to find library materials. Indeed, card catalogs no longer exist in many schools. Instead, the schools have set a goal of having students learn to effectively use search engines and to make use of the Web. Based on examples such as this, many people forecast that ICT will be the basis of a number of future changes in goals of education.

At the current time, massive efforts are underway to convert a significant amount of the world's collected books into digital form. This is a major paradigm shift in libraries. Quoting from Rouse (2005):

The digitization of the world's enormous store of library books—an effort dating to the early 1990s in the United Kingdom, the United States, and elsewhere—has been a slow, expensive, and underfunded process. But last December librarians received a pleasant shock. Search-engine giant Google announced ambitious plans to expand its "Google Print" service by converting the full text of millions of library books into searchable Web pages. At the time of the announcement, Google had already signed up five partners, including the libraries at Oxford, Harvard, Stanford, and the University of Michigan, along with the New York Public Library. More are sure to follow.

...

But others are more cautious about the leap Google's partner libraries are taking. Brewster Kahle, who is often described as an inspiring visionary and sometimes as an impractical idealist, founded the nonprofit Internet Archive in 1996 under the motto "universal access to human knowledge." Since then, the archive has preserved more than a petabyte's worth of Web pages (a peta byte is a million gigabytes), along with 60,000 digital texts, 21,000 live concert recordings, and 24,000 video files, from feature films to news broadcasts. It's all free for the taking at www.archive.org, and as you might guess, Kahle argues that all digital library materials should be as freely and openly accessible as physical library materials are now.

Now, think about some other possible paradigm shifts. As an example, suppose that we are not particularly happy about how well our students in developing a good “hand”—that is, being good at cursive handwriting. We might improve upon our current results by developing better curriculum materials, by developing pencils and pens that better fit a child’s hand, and by devoting more time to “penmanship.” An alternative is to reframe the goal. State the goal as being able to produce highly legible text in hardcopy and electronic formats. This might be accomplished by teaching keyboarding, voice input to a computer, and hand printing. Such a change in the curriculum would be a paradigm shift.

As another example, consider the current situation in which students spend perhaps six hours a day in a school building. It costs a lot of money to provide this physical facility as well as its staff. Consider an alternative of high school students coming to school only half days, and doing half of their coursework via asynchronous distance learning. This would give these students more flexibility in when they do their “coursework” and homework, and it would require only half as much classroom space. A shift from “traditional classroom instruction” to extensive use of asynchronous distance learning is a major paradigm shift (Karlin, n.d.).

If our society is serious about improving our educational system without substantial increasing funds spent on education, then significant paradigm shifts will be needed. The people developing, researching, and implementing such changes are working to invent the future of education. I predict that the next two decades will see some major paradigm shifts in education—far more than we have seen in the past four decades.

Three General Goals of Education

I enjoy reading about the history of the development of public education in the US. Here is a brief quote from Thattai (2001):

American public education differs from that of many other nations in that it is primarily the responsibility of the states and individual school districts. The national system of formal education in the United States developed in the 19th century. Jefferson was the first American leader to suggest creating a public school system. His ideas formed the basis of education systems developed in the 19th century.

The most preliminary form of public education was in existence in the 1600s in the New England colonies of Massachusetts, Connecticut and New Hampshire. The overriding belief on educating the children was more due to religious reasons and was easy to implement, as the only groups in existence were the Puritans and the Congregationalists. However, the influx of people from many countries and belonging to different faiths led to a weakening of the concept. People refused to learn only in English and opposed the clergy imposing their religious views through public education. By the middle of the eighteenth century, private schooling had become the norm.

Each person has his/her own ideas on what constitutes appropriate goals for education. Thus, this topic can lead to heated debate and is currently a major political issue. Curriculum content, instructional processes, and assessment are all controversial issues.

Each state now has a huge list of goals and detailed objectives for its educational system. These goals and objectives vary from state to state. In addition, the amount of time to be devoted to accomplishing each goal, and the nature of the assessment of progress toward achieving the goal, also varies considerably from state to state. This helps to explain why the US federal Government is placing so much emphasis on more uniform and more stringent assessment across the country.

The NCLB plan has resulted in moving funds around and making some changes in priorities. Most of the changes are not backed by strong research that suggests significant improvements will result. Many people feel that NCLB will not produce significant success in improving our educational system.

Moreover, think for a minute about the NCLB requirement that schools, districts, and states are to recruit and retain “highly qualified teachers” and to show annual progress toward the goal of 100 percent student proficiency in reading and mathematics by 2014. Ask yourself: Do we have evidence that even the best of teachers can bring 100 percent of their students to high proficiency in reading and mathematics? The future that the NCLB legislation wants to create is impossible to achieve within the confines of current technology and teacher capability.

Of course, there remains the possibility of progress in genetic engineering facilitating changes in the brains of the many students who currently have no chance of achieving the high proficiency goals. Other research is making progress in “brain pills” that significantly improve brain performance. However, I don’t think that this is what NCLB has in mind!

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, unifying goals of education:

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

These three general goals—acquisition & retention, understanding, and use of knowledge & skills—help guide formal educational systems throughout the world. They are widely accepted goals that have endured over the years. They provide a solid starting point for the analysis of any existing or proposed educational system. People developing goals for educational change need to pay careful attention to these three enduring overall goals of education.

All three goals use the term *knowledge and skills*. In this book, I use the term *knowledge* to encompass the full range of data, information, knowledge, and wisdom. Sometimes these four terms are placed on a scale (see Figure 3.1) that tends to suggest a hierarchy. Thus, memorizing and retaining data or information without understanding is at a lower level than gaining knowledge (with understanding) and wisdom.

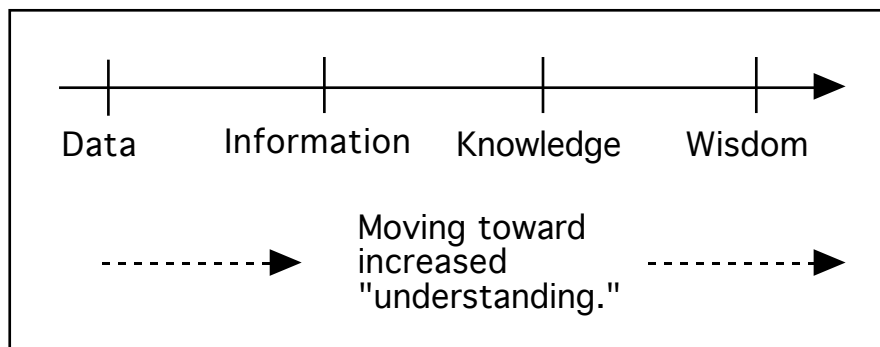


Figure 3.1. Data, information, knowledge, and wisdom scale.

The term *skills* is taken to mean both physical skills and mental skills. Thus, the term *knowledge and skills* is intended to encompass the full range of mental and physical development. A more detailed discussion of data, information, knowledge, and wisdom is given in Moursund (2005, Chapter 2).

You will notice that Perkins' three goals do not speak to the specifics of curriculum content, instructional processes, student assessment, teacher education, and other major—often controversial—issues in education. For example, Perkins does not specifically mention reading, writing, arithmetic, science, or social science. Moreover, this list does not speak to the issue of how the goals are to be accomplished. The generality of the three goals makes them quite useful in discussions about ICT and other potential change agents in education. However, it is often said, “the devil is in the details.” That certainly applies to setting and implementing goals for education.

More Details on Goals of Education

I assume that as a preservice or inservice teacher you are highly committed to helping our schools to accomplish the goals of education. Perkin's short list is useful, but provided limited details. Appendix B of this book contains a far more detailed list. More detail can be found for any particular state by looking at documents from the State Department of Education for that state.

Quoted below is a rather general set of goals that many people feel our schools should be achieving, but that are not widely being achieved (Fouts, 2003, page 27). I have seen a lot of evidence that our educational system is beginning to make major commitments to these goals. Base on this, I predict that these goals will become commonly accepted and widely implemented at a classroom level in the next two decades.

1. Student work shows evidence of understanding, not just recall.
2. Students are engaged in activities to develop understanding and create personal meaning through reflection.
3. Students apply knowledge in real world contexts.
4. Students are engaged in active participation, exploration, and research.
5. Teachers utilize the diverse experiences of students to build effective learning experiences.
6. Students are presented with a challenging curriculum designed to develop depth of understanding.
7. Assessment tasks allow students to exhibit higher-order thinking.

Notice the strong emphasis on student understanding. At the current time, the very best of human-developed artificially intelligent systems do not have anything like the levels of understanding that people have. At the current time, people are a lot smarter than computers. On the other hand, computers are far better than people at rote memorization. Many futurists predict that the gap between human understanding and computer “understanding” will narrow year by year. Ray Kurzweil (2001), for example, believes that computers will surpass humans by sometime in the middle of the current century. Kurzweil is a noted scientist, software developer, futurist, and entrepreneur. If the topic of Artificial intelligence in education interests you, then you may want to read my free short book (Moursund, 2005) on this topic.

I find it interesting to think about individual items on the seven-item list from the point of view of what changes they might suggest in our current educational system. For example, I put items 3 and 7 together, and then think about what I do for a living. I am a knowledge worker. Much of my working day is spent linked to the Internet. While I can sit and think without use of a computer, a computer and connectivity is now a routine and essential part of my professional work. Thus, if you want to assess my capabilities, you have to assess in a hands on ICT system environment.

Moreover, although I sometimes have to work within reasonably restrictive time limits, I actually have a lot of flexibility in how I use my time and how much time I have to accomplish a specific task. When faced by a task with a strict deadline, I can stay up later at night, start earlier in the morning, work on weekends, take time away from other tasks, and so on. It is seldom that I am presented with a challenging task and told that I have 50 minutes to complete the task.

What this suggests to me is that authentic instruction, authentic assessment, and a focus on higher-order thinking and problem solving are intimately tied in with having appropriate tools and having considerable flexibility in time. The in-class, 50 minute, closed book, closed computer test is not at all like the world outside of the classroom.

I imagine that similar ideas have occurred to you. As you work to invent your future and the future of your students, you might give careful thought on what you will do in this area of teaching and assessment.

Academic Disciplines

The school curriculum is divided into a number of academic disciplines or fields. At an elementary school level, for example, each teacher is responsible for teaching language arts, mathematics, sciences, and social sciences. The elementary school curriculum may also contain some emphasis on other areas such as art, foreign language, health, library science, music, and physical education. Moreover, a single topic such as science or social science is actually consists of many different large disciplines. Often a school will employ specialists to help teach the wide range of field that are important in elementary school education.

We recognize that many academic fields such as language arts, science, and social science are quite broad and contain a number of specific disciplines. Science, for example, includes the disciplines of biology, chemistry, and physics. Language arts include the disciplines of reading, writing, speaking, and listening. However, in the remainder of this book I tend to use the terms *discipline* and *field* interchangeably except where more precision might be useful.

You have some knowledge about a lot of different disciplines such as art, biology, chemistry, dentistry, economics, forestry, geography, and so on. A discipline—a coherent area of human endeavor—can be analyzed from the point of view of:

- The types of problems, tasks, and activities it addresses.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, language (including notation and special vocabulary), and methods of teaching, learning, and assessment.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.

- The knowledge and skills that separate a novice from a “reasonably competent” from an expert from a world-class expert. Each discipline has its own ideas as to what constitutes a high level of expertise within the discipline and its sub disciplines.

Thus, the problems addressed in a history course are different than the types of problems addressed in a chemistry course or in a writing course. An artist, musician, and poet produce quite different representations of a sunrise. A biologist might make use of a scanning electron microscope, but this is an unlikely tool for use in a literature course or a mathematics course. An astronomer might make use of the orbiting Hubble telescope, but this is an unlikely tool for use in an economics or psychology course.

However, there are a number of tools that cut across many disciplines. Reading, writing, and arithmetic (mathematics) are interdisciplinary tools, useful in most disciplines. That is why they are considered part of the basics of education.

ICT has similar characteristics, and this has been a challenge to our educational system. Here are two major aspects of this challenge—a challenge that will continue to exist far into the future:

1. Our current educational system devotes a huge amount of its effort to helping students achieve contemporary standards in the 3Rs. It would take significant time restructuring, curriculum revision, and teacher retraining to bring students to a somewhat corresponding level of expertise in ICT.
2. ICT is a very rapidly changing field—think of it as a moving target. Our K-12 educational system has previously never had to deal with such a rapidly moving target.

Now, let’s think beyond the basics, to other aspects of the core curriculum. An academic discipline becomes part of the K-12 core curriculum because a wide range of stakeholders view the discipline as important to a modern education. Thus, reading, writing, arithmetic (mathematics), science, and social science are parts of the core curriculum in schools throughout the world. However, the issue remains as to what level of expertise we should expect students to achieve in these disciplines, and how much of school time should be devoted to helping students gain these levels of expertise.

For example what do we want students to learn about science and how might we assess a student’s level of expertise in this very broad field? This is a worldwide question. The Third International Mathematics and Science Study (TIMSS) was designed to allow international comparisons of student expertise in mathematics and science. ICT is now an important tool in both mathematics and science, and it is also an integral component of the content of these two fields. However, ICT is not uniformly available in schools throughout the world. Thus, in an international study of student expertise in mathematics and science, what aspects of ICT in these fields should be assessed? This is an interesting question that will need to be better addressed in the future, as ICT becomes more and more important in these fields.

The term “expertise” does not mean any specific level of expertise. Suppose, for example, you are thinking about your current level of expertise in some specific small aspect of ICT, such as use of a word processor for writing and desktop publication. It might be helpful to you to use a scale such as is illustrated in Figure 3.2.

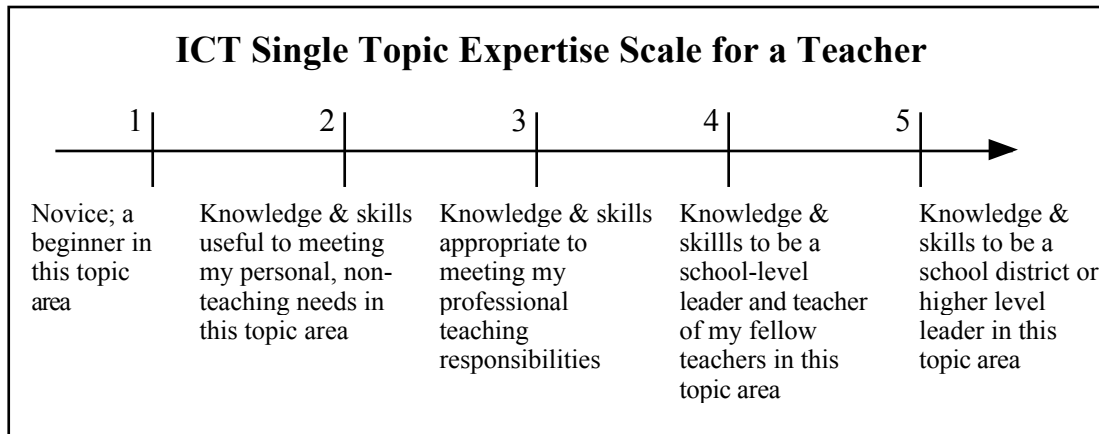


Figure 3.2. ICT single-topic expertise scale for a teacher.

Perhaps you are a “3 on this scale in the area of writing and desktop publishing using a word processor. Now, think about what might happen over the next ten years. Suppose that your knowledge and skills in this aspect of ICT do not change over that period of time. Then it is quite likely that you will then be approximately a “2.5” on the scale.

This illustrates an interesting and challenging aspect of ICT expertise. The future will bring sufficient changes to ICT in education so that unless you continue to make relatively rapid progress, you will decline on the type of expertise scale given in Figure 3.2. A similar sort of analysis can be used with the various major components of ICT in education. What paradigm shift in inservice education would be needed to adequately deal with the pace of change of ICT in education? Can you make such a paradigm shift just for yourself, as you invent your personal future?

Some Learning Theories

This section explores some of the learning theory components of the Science of Teaching and Learning (SoTL). Education can be improved by gaining increased knowledge about the SoTL and then appropriately implementing this increased knowledge. Bransford et al. (1999) is an excellent SoTL book that can be read free on the Web.

There are many ways to implement our increasing knowledge of SoTL. See, for example, Computer-Assisted Learning and Distance Learning in Chapter 8.

Constructivism

Some teachers act as if all of the students in their classes have taken and passed the required prerequisite courses, then they all have the needed knowledge and skills that the courses they teach build upon. However, we all know that in any course at any grade level there is a tremendous difference in the cognitive abilities, cognitive maturities, and knowledge and skills of the various students.

Constructivism is a learning theory that states that new knowledge and skills are built upon one’s current knowledge and skills. What that sentence is easy to memorize and seems self-evident, it is a major challenge to effectively implement constructivist-based learning theory. That is because each person has different knowledge and skills.

This presents tremendous challenges both to teachers and to learners. Such challenges are especially evident in Special Education. In Special Education, a great deal of time and effort goes into developing an Individual Education Plan (IEP) for a student. The IEP pays careful attention to the learner's current level of knowledge and skill. It then crafts educational goals and a plan of teaching/learning that is specific for the learner.

We can gain some additional insight into constructivism by looking at some research results produced by Benjamin Bloom. His research showed that with appropriate one-on-one tutoring the typical "C" student could learn at the level of an "A" student. That is, such tutoring can produce a two-sigma improvement (two standard deviations improvement) in student performance on tests over the material being taught. The following quote from Jay Gould (2003) elaborates on this situation from a distance education point of view.

The advent of the World Wide Web provided the feasibility of instant feedback between student and instructor analogous to the teaching methodology of ancient Greece. However, modern lecture halls or classrooms notably diminish the student's knowledge expectancy, suggesting a normal distribution curve. Research results affirm that learning is the sole responsibility of the student. However, unless the design team responsible for developing the distance education course addresses on-line variances and the instructors acknowledge their responsibility to provide motivation by putting a personal instructional touch into the "tube," the attainable two-sigma shift to the right will not be achieved. Therefore, has the Web's distance asynchronous on-line instruction defined a solution for the long-held dilemma of finding an educational methodology that will achieve results analogous to tutorial education and, if so, under what conditions would those similar results be achieved?

Our educational system cannot afford the costs of every student having an IEP and individual tutoring. However, well-designed interactive CAL can, in a cost effective manner, move us a significant step toward providing students with highly individualized, constructivist-based, one-on-one instruction. Thus, I forecast that CAL will become an increasing component of our educational system.

Transfer of Learning

Teaching for transfer is one of the seldom-specified but most important goals in education. We want students to gain knowledge and skills that they can use both in school and outside of school, immediately and in the future.

Transfer of learning deals with transferring one's knowledge and skills from one problem-solving situation to another. You need to know about transfer of learning in order to help increase the transfer of learning that you and your students achieve.

The Perkins and Salomon (1992) low-road/high-road theory of transfer of learning is only about 15 years old and it is an important part of SoTL. In low-road transfer one trains for automaticity, for quick and automatic response at a subconscious level. The stimulus/response is practiced in the situations (or, simulations of the situations) in which the problem-solving action is to occur. For example, a goal in reading instruction is a student to be able to recognize words quickly without conscious thought, linking the printed symbols with "meaning" stored in the neurons in his or her head. Many students gain a good level of speed and accuracy (fluency) by the time they finish the third grade. An important aspect of low-road transfer is that it can take a great deal of time and effort to achieve the needed level of automaticity. However, once achieved, much of this automaticity is maintained after a significant period of time (such as a summer) of non-use.

High-road transfer involves: cognitive understanding; purposeful and conscious analysis; mindfulness; and application of strategies that cut across disciplines. In high-road transfer, there is deliberate mindful abstraction of an idea that can transfer, and then conscious and deliberate application of the idea when faced by a problem where the idea may be useful.

Here is an example. Suppose that in math you are teaching students the strategy of breaking a large problem into a collection of more manageable smaller problems. You name this strategy “Breaking a big problem into smaller problems.” You have students practice it with a number of different math problems. You then have them practice the same strategy in a number of different disciplines.

Each discipline teaches strategies for solving the problems and accomplishing the tasks in that discipline. Good teachers teach these strategies for high-road transfer.

Situated Learning

Situated learning is a theory that indicates that what one learns is highly dependent on the environment in which the learning is situated. This is closely related to transfer of learning. Increased transfer is facilitated by having the “situation” of the learning by reasonably similar to the “situation” in which the learning is to be applied.

Our current understanding of situated learning strongly suggests that much of the instruction about ICT and use of ICT in schools is poorly conceived and poorly implemented. Outside of school settings, people do not go to a computer lab once or twice a week to do computer stuff. If they have any need to use a computer at home or work, they have a computer to use whenever they deem it appropriate. As a personal example, when I am writing (for example, preparing a lesson plan for an upcoming class), I do so in an environment of good ICT facilities (computer, connectivity, printer, and so on). Why aren’t schools providing similar environments for students?

Researchers and practitioners strongly support the ideas of case study, problem-based learning, and project-based learning as vehicles for implementing situated learning theory. Nowadays, CAL is a common aid to creating such learning environments.

Overview of ICT Uses in Teaching and Learning

There are many different ways to categorize current and potential roles of ICT in education. This book focuses on four general areas:

- Curriculum content
- Pedagogy (instructional processes)
- Assessment and accountability
- Support and capacity building for teachers, teachers’ assistants, and other professional staff.

Curriculum Content

ICT plays two major roles in curriculum content:

1. Students learn to use the tools of ICT and they learn some of the subject area that is commonly called Computers and Information Science. The International Society for Technology in Education (ISTE) has developed goals for this aspect of ICT in education (ISTE NETS, n.d.).

2. Students learn ICT that has become or is becoming part of the content of each discipline in their curriculum. For example, over the past two decades computational science has become an important component of mathematics and each of the sciences. Chapter 5 addresses ICT as an emerging content area within each academic discipline. As another example, communication using interactive multimedia is now an important component of the disciplines of reading and writing.

Think about the curriculum content of the disciplines that you currently teach or are preparing to teach. What do you know about ICT as part of the curriculum content of these disciplines? Do you know enough to self-assess using the scale of Figure 3.2? Do you know enough to make a reasonable forecast of the future of ICT as part of these content areas? What are you doing to invent your future in this aspect of the disciplines you teach or are preparing to teach?

Pedagogy (Instructional Processes)

There are a number of different technologies that can help in the “delivery” of instruction to students. Familiar and widely used examples include books, movies, audio recordings, radio, television, and film strips. Other examples include the chalkboard, overhead projector, and whiteboard.

Over the centuries, people have worked to improve the effectiveness of these aids to instructional delivery. It is obvious that students now have access to more and better books than they did a couple of centuries ago. Research supports how this contributes to students getting a better education.

On the other hand, consider the technology sequence consisting of chalkboards, overhead projectors, and white boards. It is not so obvious that the more modern of these three types of technology contributes significantly more to students getting a good education than the least modern of the three. This is an important idea to keep in mind as we look at the future of ICT in education. New and/or more modern does not necessarily mean more effective or more cost effective in accomplishing specified goals.

All of the technological aids to pedagogy given at the start of this section share a common characteristic—they are static, rather than interactive. Whatever interactivity occurs is provided by the teacher or by the students.

ICT brings some new dimensions to pedagogy. You can think of these as new paradigms in instructional delivery. Here are a couple of examples:

1. ICT has facilitated replacing card catalogs by search engines, and replacement of library “stacks” of hardcopy materials by electronic storage of the materials. A student doing a search on the Web tends to think of a search engine, a browser, and the electronic storage files as being a single entity—the Web. From this point of view, the Web is a highly interactive Global Library. The paradigm shift is from one where information is highly limited and not easily assessable to one where we are challenged by an information overload.
2. Interaction among students and the teacher in a classroom has always been a part of formal education. However, ICT brings a variety of new ways for interaction. Examples include instant messaging, chat rooms, email, and a variety of software designed to facilitate people scattered throughout the world to work together collaboratively on a project. (Groupware, n.d.) The paradigm shift in oral communication is from one in

which most oral communication is face to face to one in which there are a number of other, widely used modes for oral communication. The paradigm shift in written communication is from letter writing and a few people getting materials published in books and magazines, to email, instant messaging, Websites and Blogs,

3. Computer-assisted learning is an interactive instructional delivery system made possible by ICT. CAL includes drill and practice, tutorials, simulations, and virtual realities. CAL can be done using CD-ROMs and DVDs and it can also be done over the Web. A good example of asynchronous distance learning is CAL delivered via the Internet. Over time, we will gradually see a merger of the fields of CAL and asynchronous Distance learning. Nowadays, CAL is often Intelligent CAL (making significant use of Artificial Intelligence) and highly interactive. Thus, our educational system has a new form of pedagogy—highly interactive intelligent computer-assisted learning (HIICAL). Chapter 7 contains a deeper examination of CAL. The paradigm shift is from classroom-centered, teacher-directed instruction to asynchronous, interactive instruction being available any time, any place, on any topic.

Think about pedagogy in the disciplines that you currently teach or are preparing to teach. What do you know about ICT as part of the pedagogy of these disciplines? Do you know enough to self-assess using the scale of Figure 3.2? Do you know enough to make a reasonable forecast of the future of ICT as part of the pedagogy of these areas?

Assessment and Accountability

In recent years, assessment and accountability in education have become highly politicized. Thus, people look at the investments that have been made in ICT in education, and they ask whether these investments have led to higher test scores. They look at ICT facilities that are under used and/or poorly used, and they are disturbed by the lack of accountability.

Some school districts and states have set goals for student ICT knowledge and skills. ICT facilities and instruction on ICT are needed to help students gain ICT knowledge and skills that are assessed at a district or state level. That is, ICT has become one of the disciplines that are taught in a school. In an elementary school, for example, the ICT might be taught by the regular classroom teacher or by a specialist. At the secondary school level, students might routinely use ICT in a wide variety of the classes they are taking, and there might be ICT courses taught by ICT specialists.

ICT brings an important new dimension to assessment. Computer-assisted testing is an interactive form of testing (Rabinowitz and Brandt, 2001). The computer presents a question, analyzes the response, and then determines the next question to ask based on what a student has done up to that point in the test. Notice that this sounds a lot like HIICAL. Indeed, in HIICAL a student is continually being assessed. The assessment might be used just to guide the interaction between the student and the computer system. However, it might also be used to provide reports to the teacher on a student's progress.

Think about assessment in the disciplines that you currently teach or are preparing to teach. What do you know about ICT as part of the assessment of these disciplines? Do you know enough to self-assess using the scale of Figure 3.2? Do you know enough to make a reasonable forecast of the future of ICT as part of the assessment of these areas?

Support and Growth of Professional Staff

For many years, now, educators have worked to instill into students the concept of lifelong learning. Moreover, this concept has become an important component of a teacher's personal career. While the requirements vary from state to state, all teachers and school administrators learn on the job and continue to learn throughout their professional careers.

The three previous subsections of this chapter have asked you to think about your current level of ICT expertise with respect of curriculum content, pedagogy, and assessment. In these three areas we can expect substantial changes in the future.

Thus, as you work to build and maintain your level of ICT expertise in these aspects of your professional career, you face a moving target. Fortunately, you have a couple of things going for you:

1. ICT can be learned on the job. You can create environments in your classroom that will help you to learn on the job.
2. ICT provides important aids to learning. Of course you want to have your students learn to learn with the aid of ICT. You can do the same thing for yourself!

Concluding Remarks

Formal education (schooling) at the precollege level is a huge, worldwide enterprise with a 5,000-year history. Over this 5,000-year period of time there have been substantial changes, such as:

- A gradual but pervasive trend toward educating all people.
- A gradual but pervasive trend to increase both the breadth and the depth of the curriculum, by increasing the number of years of formal education that people receive and by increasing standards.
- The introduction of new content, driven by increasing content knowledge in each discipline and the development of new disciplines.
- The development and use of new teaching techniques.

Now, education systems throughout the world tend to have reasonably well defined goals and have established standards helping to define what it means for a student or school to meet the goals. In recent years in the United States, this goal setting and standards trend has been accompanied by an increased emphasis on assessment and accountability.

ICT plays two major roles in the areas of goals, standards, assessment, and accountability:

1. First, ICT provides aids to the teaching, learning, and assessment processes in every discipline.
2. Second, ICT is an important aspect of the content of each non-ICT discipline and is an important discipline in its own right.

Clearly, ICT is a growing challenge and opportunity for our educational system and for every teacher.

Personal Growth Reflections and Conversations for Chapter 3

1. Make a mental list of some aspects of ICT that you and/or others think are important in education. Then do some self-assessment (using the scale in Figure 3.2) on these aspects of ICT in education. When you are done, share your results with some of your colleagues.

Activities for Chapter 3

1. Consider the diagram in Figure 3.3. As a preservice or inservice teacher, discuss what this diagram means to you and your roles as teacher.

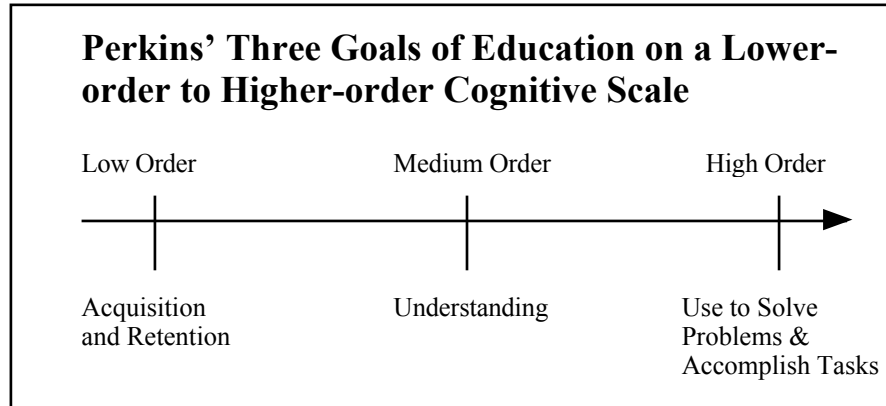


Figure 3.3. Lower-order and higher-order cognition and education goals.

2. Select some aspect of ICT in education, such as use of a word processor as an aid to writing and desktop publication. For the topic you select, select a grade level and then name some goals and objectives that you feel might currently be reasonable for this aspect of ICT in education. Next:
 - A. Analyze your goals and objectives from the point of view of the diagram given in Figure 3.3.
 - B. Forecast changes that you expect to see in your list of goals and objectives over the next decade. Explain your thinking and reasoning behind these forecasts.

Chapter 4: The Art and Science of Planning

If you don't know where you are going, you're likely to end up somewhere else. (Lawrence J. Peter)

"A pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty." (Winston Churchill)

The literature on long-range strategic planning tends to focus on an organization (country, school district, company) doing the planning. You can view this chapter as a “translation” of such literature into a form that fits an individual person.

The type of strategic plan discussed in this chapter is a long-range plan that covers a period of about five years. Five years is long enough to implement a significant and long lasting change in a person or organization.

Generally, completion of a long-range strategic plan then leads to the development of a medium-range plan that covers two to three 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 and environment (for example, your job situation) that will be available during the coming school year.

Reviewing “Where We’re At” and “Where We’re Going” in this Book

This book is designed to help you plan for some of the ICT in education aspects of your future. The first three chapters have provided you with some general background about education and ICT in education. Now we are ready to get down to the business of helping you to invent your future in ICT.

If you are at all like me, you want to jump right now to the heart of the matter. For example, you might be thinking, “Tell me what the future of ICT in education will be. Then I can begin to do some planning for myself or my school.”

My response is “whoa.” I think that I know some things that will help you. First, there is a lot known about the process of developing a long-range strategic plan. I want to share a summary of that with you. That is what is done in this chapter.

Second, I will indeed provide you with a number of forecasts on the future of ICT in education. But it is important that you become a critical consumer of such forecasts. So, I want to teach you a little bit about the art and science of forecasting. You need to know enough to decide the extent to which you are willing to act on the forecasts that I provide and that other people provide. That is done in the next chapter.

This chapter examines both the “art” and the “science” of planning. While the emphasis is on ICT in education, a number of the ideas are more widely applicable. Planning is based on forecasting the future. A planner forecasts the future and compares this possible future with what he or she would like the future to be. The planner then develops a plan designed to produce a future more to his or her liking. Thus, planning and forecasting are intertwined.

Mission, Process, and Product

Many people view the start of a new year as a time to reflect about “where they are going.” In some sense, they think about their “Mission” in life, and what they can do to better

accomplish this mission. Perhaps they develop some New Year's Resolutions that are consistent with and supportive of their mission.

The chances are that you have made some New Year's Resolutions. If you make such resolutions, the chances are that you don't follow through and successfully implement most of the resolutions.

The same thing can easily happen as you work to invent your ICT in education future. It is easy to think about things that you will do. It is much more difficult to develop a realistic plan, begin implementing it, evaluate your progress from time to time, and revise your plan as needed so that works better in moving you toward your goals.

Long-range strategic planning is a process that leads to a product. The goal is to better accomplish a mission. 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.

Some Keys to Success

Each person and each organization is unique. Many people and organizations find that the process of developing a strategic plan contributes as much or more than does actually having such a plan in hand. A strategic plan that is copied from the planning done by another person or organization is apt to be of little value. Think about this as you develop your personal plan for inventing your personal future!

In planning for your ICT in education future, think carefully about what you can change and what you cannot change. The Venn diagram of Figure 4.1 suggests that there is no clear dividing line between what you can change about the future, and what you cannot change.

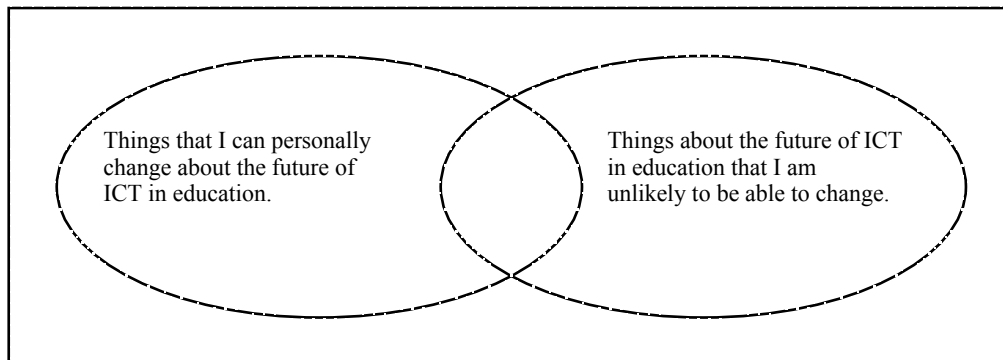


Figure 4.1. What I can change and not change about the future.

For example, the chances are that you cannot change the speed and the manufacturing cost of the microprocessor chips being manufactured by the leading companies in this field. (If you hold an appropriate very high level administrative or research position at Intel, you might well be able to change this aspect of the future.) On the other hand, you can change your personal ICT knowledge and skills, and how you make use of your ICT knowledge and skills.

The overlap region in the Venn diagram represents areas in which you interact with other people (stakeholders), rules, regulations, and other parts of your work environment that you

might be able to influence if you put sufficient effort into it. For example, suppose that the classroom in which you teach lacks sufficient electrical outlets to support the number of computers you would like to have in your room. You might think about buying a number of extension cords and power bars. But, this may well be against the rules of the city Fire Marshall or the school district's insurers. If you take the issue to the Principal, Central Office, or School Board, you might be able to get someone to authorize and pay for the needed rewiring in your classroom or school.

There is a substantial amount of research literature about LRSP. Here are four keys to success:

1. Adequately and appropriately involving all of the key stakeholder groups—both those that will be affected by the outcomes produced by implementing the plan and those who will be doing the implementation. For example, your students and their parents are stakeholders. The teachers who will have your students next year are stakeholders. As you change yourself and what you do, you will be affecting these stakeholders. If they don't like what you are doing, this might make it difficult for you to make the changes,
2. Recognizing that one of the major aspects of the planning process is educating the planners and the stakeholder groups that they represent. Of course, this also means that you need to educate yourself!
3. Build on reality rather than “pie in the sky.” Think carefully about the resources that are currently available and the resources that are likely to be available. It is certainly all right to plan on writing grant proposals and to plan on seeking out other sources of resources. But, then you should develop alternate plans—a plan that can be implemented using resources that are quite likely to be available, and a plan that can be implemented if the additional resources become available.
4. Making and ensuring implementation of appropriate provisions for the annual review and update of the plan.

Six Key Steps in Strategic Planning

This section outlines a six-step strategic planning process that can be used for personal planning or by an organization.

1. Evaluate the Situation

The starting point for strategic planning is a careful evaluation of the current situation.

- 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 your strategic plan proceeds over the years. For example, what ICT resources are currently available to you and your students, and how are the resources being used? Make sure you include a description of the hardware and software you and your students have available for use at home.
- Gather and analyze data on what is working well and what is not working well. For example, what are the current uses of ICT in your classroom and other professional work? What are students learning about ICT relative to standards that others set and relative to standards that you want to set?

- Analyze the environment and the planning assumptions. Identify the key stakeholders and their beliefs and goals. Which of the stakeholder groups might be supportive of your planning and implementation efforts, and which might oppose what you have in mind? What resources are you assuming will be available? Are you assuming that you will write some grant proposals and be successful in getting these proposals funded? Moursund (2002) is a free online book about grant writing and other ways for obtaining resources for ICT in education.

2. Articulate a Vision

Although long-range strategic planning usually focuses on a five-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 first year teacher doing visioning for 15 years into the future.

I can already see that I know more about ICT in education than many of the experienced teachers in my school. I see that many have had the opportunity to learn more about ICT and to implement their knowledge and skills—but they haven't.

I don't want to be like them. I have been going to school and learning a lot for the past 17 years, and I want to keep learning at a fast pace. I don't want to be one of those teachers who seem to "die on the vine."

My goal as a teacher is to "be all I can be." I can see that ICT is an open path, and that I can excel in this area. I vision myself as a school and district leader in ICT within 10-15 year, and then moving forward from there. By then I would like to doing quite a bit of staff development and materials development.

Such very long-range visions are painted in very broad strokes.

3. Decide on a Mission Statement

A mission is an ongoing purpose. It should be simple, direct, and easy for you and other people to understand. Here is an example of an ICT in education mission statement for a school or school district:

To ensure that all of our students have ICT knowledge and skills at a level that meets their current education and other needs, and that prepares them for the ICT learning that will be necessary to meet their future needs.

Here is an example of an ICT in education mission statement for a person:

To become the best ICT-using teacher in my school and one of the best in my school district.

Of course, a mission statement can be dynamic. For example, perhaps you remember the TV series *Star Trek*.

"Space...the final frontier...these are the voyages of the Starship Enterprise—its continuing mission to explore strange new worlds, new life, and new civilizations...to boldly go where no one has gone before ..."

4. Propose and Select Goals

A goal is an accomplishment, an outcome or result, which happens by a stated time. Objectives provide more detail—think of them as subgoals. Here is an example for a tenth grade teacher.

Goal Example # 1: I will significantly improve my productivity in three major non-teaching aspects of my work during the first year, and add another personal productivity tool to my repertoire each subsequent year.

Objective 1: I will learn to use and then regularly use an electronic gradebook, including the features of automatically sending grade reports to students via email.

Objective 2: I will word process and carefully save (in a manner that I can find them in the future) all handouts, quizzes, tests, and other materials that I prepare for my students.

Objective 3: I will learn how to develop an email Distribution List. Then I will develop and routinely use such a list for each of my classes.

Objective 4: In the Spring I will decide on another productivity tool I will add to my repertoire for the next year.

Here is a second example, this time a goal set by this fifth grade teacher.

Goal Example # 2: All my students will be able to make effective use of a word processor to do process writing by the end of the fifth grade.

Objective 1: All students will be comfortable at composing at a computer keyboard in a word processing environment.

Objective 2: All students will routinely make use of the spelling checker and grammar checker as they compose documents while using a word processor.

Objective 3: All students will be able to touch keyboard at a speed in excess of 25 words per minute by the end of the fifth grade.

Objective 4: All students will know and routinely use basic design principles and standards of contemporary desktop publishing.

The goal focuses on students becoming skilled at using a word processor in process writing. Process writing includes a “publication” step. The objectives include more detail of what is expected of the students. For the most part, the objectives are measurable objectives. However, Objective 4 fails to say what is meant by “basic design principles and standards of contemporary desktop publishing.”

Moreover, this goal does not say what the teacher will do. In essence, it is a goal for other people (the teacher’s students), rather than a goal for the teacher. Here is an example of a better approach:

Revised Goal Example # 2: I will create a learning environment and I will teach in a manner so that all of the students who are with me for the full year have very good opportunities to learn to make effective use of a word processor in doing process writing.

Objective 1: I will make arrangements so that there are eight networked computers in my classroom, and I will make arrangements so that my students can easily go to the library to use computers there.

Objective 2: During the fall semester, each student will receive 30 hours of hands-on instruction and practice in keyboarding. (The computer lab instructor has agreed to provide this instruction.)

Objective 3: In my day to day teaching, and in all of the handouts I provide to my students, I will role model effective use of computers in doing process writing and desktop publication.

Objective 4: I will provide explicit instruction to my students on process writing and desktop publication in a word processing environment, and I will give my students one assignment each week in which they are required to write and desktop publish using a word processor.

This is much better than the original Goal Example # 2. Now the teacher is saying things that he or she will do to accomplish the Revised Goal Example #2.

Research on strategic planning suggests that a relatively limited number of overarching goals is to be preferred over a large number of more limited goals. Thus, rather than develop a plan with dozens of goals, it is better to develop a plan with fewer than a half dozen goals. Each goal should have a limited number of objectives—perhaps as few as two or three. This means that as a planner, you are faced by two major tasks:

1. Consolidating goals into overarching goals, and consolidating lists of objectives into overarching objectives.
2. Winnowing down the lists of goals and objectives.

This is not an easy task. Whatever the process you use, sort out the Critical Success Factors—those goals that are essential to achieve your mission. Estimate what resources will be needed to achieve these essential goals and deduct them from the list of possible resources. Then consider the other long-range goals and objectives. Goal development and winnowing needs to be based on the realities of what resources are available for implementation. Indeed, in the planning process, it is common to cycle repeatedly between steps 4 and 5 in the list that you are currently reading.

5. Develop a Strategic Implementation Plan

At this stage of the planning process you have a mission, goals, and objectives. The goals and objectives are aligned with the mission, so that accomplishing them clearly contributes to achieving or moving toward achieving the mission.

The next step is to work on a plan of what you will actually do and what you will expect others to do. For example, suppose that you are the 10th grade teacher who has set the personal goal given in the previous section. You have said:

I will significantly improve my productivity in three major non-teaching aspects of my work during the first year, and add another personal productivity tool to my repertoire each subsequent year.

You have also specified four objectives. But, what specifically will you do to accomplish each objective, when will you do it, and how will you tell if you are making appropriate progress, and how will you tell when you are done?

For each objective, you need to develop a reasonably detailed plan. Here is an example:

Objective 1: I will learn to use and then regularly use an electronic gradebook, including the features of automatically sending grade reports to students via email.

Our school district has a district site licence for an electronic gradebook. I'll find out how to download the software to the computer on my desk at school and to my home computer, and then do the downloading. The Central Office staff provide a free half day workshop on use of this

gradebook, and it also provides quick response answers to questions sent in by email. I will take the course next month and then begin experimenting immediately. My good friend Pat who already uses this gradebook software has agreed to help me get started. By the time school ends this June, I will have had about two months of practice, and I believe I will be well qualified to use the electronic gradebook in all of my classes starting next fall.

Or, consider the fifth grade teacher who has set the goal and objective:

Revised Goal Example # 2: I will create a learning environment and I will teach in a manner so that all of the students who are with me for the full year have very good opportunities to learn to make effective use of a word processor in doing process writing.

Objective 1: I will make arrangements so that there are eight networked computers in my classroom, and I will make arrangements so that my students can easily go to the library to use computers there.

With this goal and objective in mind, the fifth grade teacher now needs to write how to achieve getting eight networked computers in his or her classroom. Probably few or none of the other teachers in the building have this many computers in their classrooms. Moreover, there may be wiring problems and space problems. And, do the principal and the librarian want your students going to the library whenever they need access to a computer, and the eight machines in your classroom are all in use? Will other teachers be unhappy about the facilities and access arrangements you are making?

As you develop detailed plans for accomplishing your goals and objectives, you may well run into situations in which it seems unlikely you will be able to accomplish a goal or some of its objectives. That sends you “back to the drawing board.” You need to rethink the role of this goal and/or objectives that you will not be able to accomplish. Can you accomplish the goal in a different manner? Is the goal essential to your mission? Can you accomplish the mission through other goals? You might need to go all of the way back and revise your mission.

6. Periodic Assessment and Update

Evaluation must be an ongoing part of strategic implementation. A key idea is that results from the evaluation are fed back 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.

Here is an interesting way to approach some of this evaluation. Talk to a close friend about your long-range goals and plans for ICT in education. Tell your friend that it would be really helpful to you if you could get together for an hour each month so that you could share details about how what you have done during the previous month, what is working well, and what is not working well. This type of sharing is apt to help you in sticking to your plans!

Avoiding Failure of the Planning Process

A person (or group) approaches strategic planning assuming that that the process and its implementation will be successful. However, the plan may fail. There are four obvious reasons for this; they can be avoided by taking appropriate care in the planning process.

1. The planning process is carried out in a poor fashion. Inadequate time, energy, and other resources are devoted to the task. The resulting plan is not visionary enough, contains major flaws, and is not worth implementing.

2. The planning process does not adequately involve the key stakeholders—the people who are affected by the plan and who will be involved in implementing it. Consequently, they do not support the plan, and they sabotage implementation of the plan. They may do this in a quite passive manner by merely not putting their energies and “clout” into getting the goals accomplished.
3. The plan is not periodically updated based on formative evaluation data gathered during implementation of the plan. The plan quickly becomes outdated and is ignored. This has commonly occurred for ICT plans that schools and school districts have developed over the past decade or two.
4. A major and unforeseen change occurs that undermines the plan’s assumptions. What happens if the school’s technology coordinator leaves to go to graduate school or the principal who strongly supports your plan decides to retire? Note that it is possible to do contingency planning for various types of disasters. A final plan can be examined in light of a variety of scenarios that the original planners might not have considered. A well-designed, robust plan will stand up under such scrutiny. A sturdy planning process can survive most unforeseen events.
5. Think about the possibility of paradigm shifts. Imagine some possible shifts, and think about how your plan might accommodate them.

Don’t Set Yourself Up for Failure

It is easy to set yourself up for failure. 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 ICT point of view. Most of these criteria are applicable to you as a person doing planning for yourself.

1. Do not escalate teacher workload. While ICT 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.
2. 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.
3. Avoid extreme demands on teachers’ skills and talents. The field of ICT in education is extensive and growing. It takes a great deal of knowledge and skills to function well in this field.
4. Include strong materials support. Teachers need good instructional materials, and students need good learning materials, for technology in education.
5. Do not boost the school costs per student a lot. At the current time, ICT hardware and software are add-on expenses in education. Careful thought needs to be given as to whether the added ICT expenses will lead to decreases in other expenses.

6. Fulfill many conventional educational objectives at least as well as conventional instruction. Stakeholders are not happy if ICT leads to decreases in student performance in traditional academic areas.

Concluding Remarks

ICT is but one of many rapidly changing technologies that will affect your future. ICT will certainly have a large effect on schools, teachers, and students. Thus, you will be involved in the changes, whether or not you plan for and prepare for them.

If you plan for and prepare for the changes, you can be an active participant in the changes, and you can shape your life so the changes are beneficial to you and to your students.

Personal Growth Activities for Chapter 4

1. What are your 15-year visionary goals for your future of ICT in your career? How do these goals fit with your current knowledge, skills, and experience? How much time and effort are you willing to devote to achieving your visionary goals? Spend some time thinking about these ideas. They spend some time talking about them with a close personal friend.

Activities for Chapter 4

1. Analyze your school or a school that you know well. How affectively are its ICT resources being used? Note that this is not an easy question to answer. You will need to develop (and justify) the measurement criteria that you use to answer the question.
2. The chances are that your school or school district has a long-range strategic ICT plan. Look into the process that was used to develop the plan and that is used to periodically update the plan. Analyze the planning process and its results.
3. Analyze the school in which you are teaching, or some other school. To what extent are the key stakeholders in the school committed to implementing the current school or school district LRSP for ICT in education?

Chapter 5: Art and Science of Forecasting

Prediction is very difficult, especially if it's about the future.
(Nils Bohr, Nobel laureate in Physics.)

Never doubt that a small group of thoughtful committed citizens can change the world: indeed; it's the only thing that ever has. (Margaret Mead)

In this book, I use the terms *forecasting* and *predicting* interchangeably. Inventing your future is based on developing a plan and accurately predicting what the outcome will be if you implement your plan. Some aspects of the future can be predicted quite accurately, many years in advance. For example, it is possible to accurately predict the time of sunrise and sunset at a particular location on earth many years in advance. Weather forecasting is more problematic. We have grown accustomed to statements such as “there is a 60% chance of showers tomorrow morning.”

In this book, we are specifically interested in various aspects of the future of ICT in education. Some of these aspects can be predicted with a fairly high likelihood of success. Other predictions are quite problematic. Indeed, for many of them we don't even know enough to make a good estimate of the probability that our forecasts will prove to be accurate.

In terms of inventing part of your future, quite likely you will want to make sure your long-range strategic plans are rooted in predictions that have a relatively high likelihood of being correct. You should be aware, however, that there may be a significant difference between a forecast of what your plans will produce and what actually happens. Good planning (with contingency plans), good implementation, good leadership, periodic revision of the plan, and flexibility are all needed to produce acceptable long-term results.

A Few Amusing Quotes

This section contains a few examples of forecasts that proved to be incorrect. They may serve as a warning to those who believe that forecasting is an exact science. As you read these forecasts, try to imagine the time and situation in which they were made. Try to imagine whether these were merely guesses not rooted in good knowledge, or whether there are other reasons why the forecasts proved to be so inaccurate.

Louis Pasteur's theory of germs is ridiculous fiction. (Pierre Pachet, Professor of Physiology at Toulouse, 1872.)

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.)

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.)

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.)

I think there is a world market for maybe five computers. (Thomas Watson, chairman of IBM, 1943.)

Computers in the future may weigh no more than 1.5 tons. (Popular Mechanics, forecasting the relentless march of science, 1949.)

A few decades hence, energy may be free—just like unmetered air." John von Neumann, 1956.

But what ... is it good for? (Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.)

640K ought to be enough for anybody. (Microsoft Chairman Bill Gates, 1981, referring to a memory addressing system that can only address 640 K or primary memory in a microcomputer.)

The concept is interesting and well-formed, but in order to earn better than a 'C,' the idea must be feasible.—A Yale University management professor in response to Fred Smith's paper proposing reliable overnight delivery service. (Smith went on to found Federal Express Corporation.)

Knowledgeable people made essentially all of these forecasts. For the most part, however, the people did not display good insight into the developing science and technology related to their forecasts and/or good insight into the nature of people who might want to make use of the emerging technologies.

Introduction to Forecasting

It is possible accurately to predict the time of an eclipse of the sun or the moon many years in advance. It is possible to accurately predict what will happen when an acid and a base are brought together in a chemical reaction. It is possible to accurately predict the path and periodicity of a swinging pendulum. There are many other areas in science in which people can accurately predict what will happen under certain carefully specified circumstances. Indeed, science can be thought of as a field in which many such accurate predictions are possible.

Not all fields of science are equally amenable to accurate forecasting. Consider weather forecasting, which is part of the field of meteorology (Anderson, 2001). It is obvious that weather forecasting has made great progress over the past few decades. Satellites and other aids to measuring the current weather conditions have contributed significantly to improving weather forecasting. Increasing knowledge of the underlying theory of weather, computer modeling, use of computers to analyze weather data, more and better data gathering stations—all have contributed. One might expect that as computers get faster and faster, we will get more and more accurate long range weather forecasts. However, in recent years, chaos theory has emerged as a new field of study. When applied to weather forecasting, chaos theory suggests the impossibility of really accurate long-range weather forecasting (Rae, n.d.).

There are many other fields in which people would like to be able to make accurate predictions. For example, is it possible to accurately predict how well people will do in high school based on how well they have done in earlier grades? Is it possible to predict how well people will do on the job based on how well they have done in school? Is it possible to accurately predict how well a product will sell or how popular a movie will turn out to be before it is produced? Is it possible to forecast the future of information technology in education well enough to provide a basis for your personal long-range strategic planning for ICT?

These are hard questions. I believe the answer to the last one is “Yes.” But, you need to think carefully about your planning assumptions. For example, some progress is occurring in using

brain waves to control devices outside of the brain. Thus, it is possible that someday we may well have a reliable way to input words directly into a computer just by thinking the words. From this you might conclude that there is little sense in you learning to keyboard well or you learning how to teach students how to keyboard well. The problem with this analysis is that the “thinking” input to computers may be many decades away. Moreover, it might be both expensive and take more training than is needed to learn how to keyboard well.

This example is made more down to earth if you think about voice input to computers. Twenty years ago, voice input was a rather far out idea. Now, the software and microphones to do this are inexpensive and the overall system works relatively well. Thus, your personal long-range plan for ICT might well include obtaining the necessary facilities for voice input and learning how to effectively use them.

Some Widely Used Forecasting Techniques

As we attempt to make useful forecasts about the future of information technology in education, we must freely admit that these forecasts might best be classified as educated guesses. A standard approach to handling such forecasting difficulties is to make use of multiple methods and multiple forecasters. As you read this section, you should keep in mind that the types of forecasting being discussed are not an exact science. However, by use of multiple methods of forecasting and careful thought, it is possible to develop ideas and forecasts that will be useful in doing long-range strategic planning for information technology in education.

S-shaped Growth Curve

When a new technology is invented, initially there is no infrastructure to support the technology. The market for the technology has not yet been developed. Few people know about the technology and its possible uses.

The adoption of a new technology usually follows an S-shaped growth curve, such as is illustrated in Figure 5.1. Initially, adoption of the technology moves slowly. Eventually the infrastructure, demand for the technology, and other conditions become right to support rapid adoption. Eventually the demand is satisfied (the market becomes saturated).

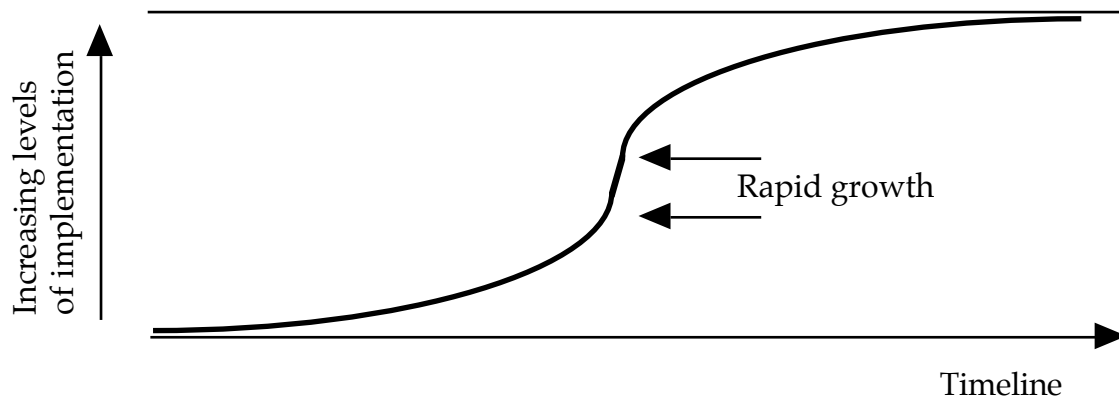


Figure 5.1. S-shaped growth curve for adoption of a new technology.

Consider television as an example. When television was first invented, there were no television stations, no television sets for sale in stores, no television programs, and so on. It took quite a while for the infrastructure to be developed. In addition, the new product had to compete with radio, movies, live theater, sporting events, and so on. Initially its quality was low and its

price was high. All of these things caused an initial slow rate of growth in the development of the television industry.

Moreover, World War II intervened, greatly slowing the development of the infrastructure. Of course, one can argue that the war also greatly speeded up the improvements in electronic technology and that this contributed greatly to the eventual success of television.

Gradually, the barriers to development and growth of the television industry were overcome. More and more people decided to purchase television sets. The industry experienced rapid growth. The middle part of the S-shaped growth curve shows this type of rapid pace of adoption.

Eventually the market for television sets matured. The market became saturated. Growth in sales slowed. The television market became a replace-and-upgrade market.

Television, like many other technologies, has undergone more than one S-shaped growth curve. For example, color television was developed and it led the television industry in another growth spurt. High definition television (HDTV) is just now leading to still another growth spurt. Perhaps sometime further in the future, holographic television will lead to another growth spurt. Such multiple S-shaped growth curves are common in high-tech fields such as the computer industry. This is illustrated in Figure 5.2.

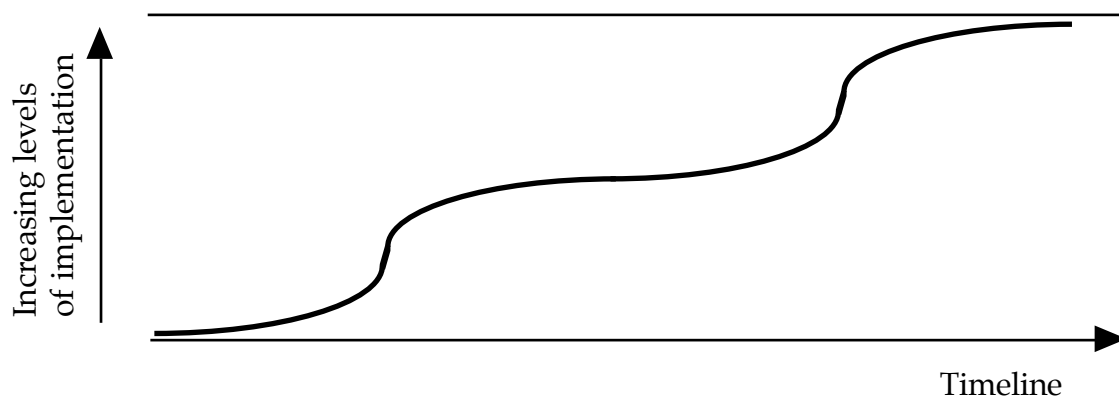


Figure 5.2. Multiple S-shaped growth curves.

The S-shaped growth curve tends to be particularly useful in forecasting the growth of sales of a consumer product. In this situation, the end user of the product is the one making the decision as to whether to purchase the product. Notice that this does not describe the past and current situation of computers coming into schools. In schools the end users—the students, teachers, and support staff—typically have little voice in decisions about acquiring computer hardware and software.

However, from the time that microcomputers first began to come into schools (about 1977) until about 2001, the growth of microcomputers in U.S. school followed an S-shaped growth curve. The total number of microcomputers computers in schools reached an average of about one per five students. Since then, school budgets have been adversely affected by a downturn in the national economy and the economy in most states. By 2005, the average number of microcomputers in school has grown to about one per 4.2 students, and there are beginning to be some schools that have a laptop for each student. It is clear that the end user (students) would like to have much better access to microcomputers in schools. However, they are not the ones making the purchasing decisions.

Mathematical Modeling

Gordon Moore was one of the founders of Intel Corporation. Many years ago he observed:

- The density of electronic components on a chip is doubling every 18 months.
- The cost of a given amount of computer power is decreasing by 50% every 18 months.

These two observations (forecasts) have proven to be approximately correct over a period of about 40 years, and are called Moore's Law (Moursund, 1998). In recent years, there has been substantial debate as to how long this pace of change will continue. Physical limitations are being reached, and the costs of building a factory and the machinery to build such chips is increasing rapidly. Still, (as of 2005) Gordon Moore and others think that his "Law" may continue to hold for another 8 to 10 years (Niccolai, 2005).

Moreover, new technology is being developed that may further extent this remarkable pace of change we have seen over the past 40 years. An example of this is the crossbar latches being developed by Hewlett-Packard. Quoting from HP Researchers (2005):

Challenging a basic tenet of the semiconductor industry, researchers at Hewlett-Packard Co. have demonstrated a technology that could replace the transistor as the fundamental building block of all computers.

The devices, called crossbar latches, could be made so small that thousands of them could fit across the diameter of a human hair, enabling the high-tech industry to continue to build ever-smaller computing devices that are less expensive than their predecessors.

...

But the pace of Moore's Law can't continue forever, and the high-tech industry has been scrambling to develop workarounds for the day - expected in a decade or so - when transistor dimensions become too small for the materials commonly used today.

"If we're going to extend Moore's Law for another several decades, we've got to have an alternative strategy," said Phil Kuekes, one of the paper's authors at HP Labs. "This is the final piece of the puzzle in what HP has been putting together as such a strategy."

Moore's Law is an example of a simple formula (a simple mathematical curve) that accurately fits a set of data. Figure 5.3 shows the approximate speed of medium-priced microprocessors over a period of many years. During that time, the speed of the chips has steadily increased from 1.5 megahertz (MHz, or millions of cycles per second) to its current gigahertz levels.

Year	Speed	Change Factor, per Two Years
1984	1.5 MHz	
1986	3 MHz	2
1988	6 MHz	2
1990	12 MHz	2
1992	24 MHz	2
1994	50 MHz	2.1
1996	110 MHz	2.2
1998	255 MHz	2.3

2000	660 MHz	2.4
2002	1,530 MHz	2.5
2004	Here we are beginning to see dual processors and 64 bit processors. In early 2005, the fastest widely sold 32 bit processors were a little over 3,000 MHz in speed.	

Figure 5.3. Speed of a medium-priced microcomputer.

The data in Figure 5.3 suggests that the speed approximately doubled every two years for a number of years, and then began to increase at still a faster pace. Looking at the data, you might be tempted to forecast that the speed in 2004 will be approximately 2.6 times the speed in 2002, or approximately 3,979 MHz. Applying the same logic, you would forecast a $2.7 \times 3,979 = 10,743$ MHz (that is, in excess of 10 gigahertz) speed for 2006.

However, such a forecast might prove way too low. Quoting from Otis Port (2005,):

Now, IBM is gearing up to manufacture the first prototype of their concept for a radically new computer-brain chip. If it delivers what Burger and Keckler promise, high tech gurus are betting it will span a new family of superchips from Big Blue—chips capable of crunching a trillion calculations every second.

Such blistering speed would itself be amazing; it's roughly the oomph of a \$50 million supercomputer in 1997.

...

The brain in Sony Corp.'s PlayStation 3 video-game console, slated to hit Japanese markets late this year, will contain nine processors: a PowerPC overseeing eight simpler processors. This multicore chip, called Cell, was developed jointly by IBM, Sony, and Toshiba. Sony claims the Cell will make the PlayStation 3 as powerful as Deep Blue, the IBM computer that dethroned chess champion Garry Kasparov in 1997.

We all know, of course, that this type of faster than exponential growth rate cannot continue indefinitely. We are already seeing clear signs that emphasis is changing from making great leaps forward in the speed of a single microprocessor chip, to use of multiple multiprocessor (multicore) chips and other approaches to increasing the overall compute power of a microcomputer. The material quoted above suggests that have not yet seen the end of the very rapid growth in computer speeds.

Trends and Megatrends

John Naisbitt's popular *Megatrends* books make predictions based on identifying major trends of change that are going on in our society, and then assuming that these trends will continue. He calls such major trends of change *megatrends*. Many of these megatrends discussed in his books have been identified by content analysis of periodicals. In this type of content analysis, the content of large numbers of periodicals are examined. Frequency counts are done on how often various topics are mentioned. Increasing and decreasing trends of frequency of mention of various topics can be counted and analyzed.

For example, the beginnings of hypermedia are frequently attributed to some of the mid 1940 writings of Vannevar Bush, although the term was not invented at that time. It is possible to search a number of different sources such as magazine article titles, journal article titles, dissertation titles—or even the entire contents of such publications—for the occurrence of the term “hypermedia.” In some initial year, there may be only a few mentions of the term. The next

year, there may be more. Eventually a pattern of year-to-year rapid growth emerges in use of this term. This pattern can be compared with the frequency of occurrence of other related terms. Such an analysis helps to identify increasing trends that have become widespread.

For a second example, one might do a count of the number of articles discussing home use of computers that appear in the 20 most widely sold magazines in the United States. If the initial count is done for magazines published in 1960, there would be few articles. This situation would continue, year after year, perhaps with a small increase, due to timeshared computing becoming available. A high rate of increase would occur in about 1975, due to the initial availability of microcomputer kits designed to be built by computer hobbyists. A further major increase would be found when commercially built microcomputers began to come to market. This type of analysis would point to the growth in public interest in microcomputers.

At one time, this type of content analysis work was done by hand. Now, computers are used to scan through the texts of a large number of publications and keep detailed records of the occurrences of specified terms. There are now a number of commercial services that have the capability of performing this type of content analysis.

However, it still takes considerable knowledge to effectively conduct such research. A person who is an expert in a particular domain tends to have the knowledge and an “intuitive feel” needed to detect changes in the domain. The combination of various forecasting techniques such as content analysis and expert knowledge is the basis for many forecasts that prove to be relatively accurate.

Here is an example of a forecast for needed change in the construction of schools based on forecasts of trends in schooling (DeArmond et al, 2002). The quoted material includes a list of five educational trends that the authors have identified.

Forward-thinking educators usually accept the idea that tomorrow’s classrooms will look different than today’s. Instead of large schools, 52-minute class periods, and rambling curricula, they foresee classrooms and schools that are personalized and focused; they look for teachers that will emphasize mastery over breadth. Whether these aspirations are realized now or years down the road, they are unconstrained by the current routines found in America’s schools. Innovative educators realize that industrial-age assumptions about learning—that everyone learns the same way; that there are “smart” kids and “dumb” kids—are obsolete. Tomorrow’s classrooms will be based on something different.

...

1. Pressure on schools to perform for all students, not just those who learn best in traditional settings;
2. Demands for the personalization of learning, so that every child has a chance to learn and families have choices;
3. New technologies that will change how teachers teach and students learn;
4. Periodic shortages of teachers (and school leaders) linked to swings in the economy;
5. Shifts in student population and residency patterns that will affect not only the demand for schools, but also the demands on schools.

Let’s assume that trend analysis was accurately done, and that the five statements given above are based on the trend analyses. What reasons do we have for believing that these will lead to any changes in our educational system? Perhaps some of the statements just reflect wishful thinking. This is where the “art” of forecasting comes into play. You might want to examine each of 1-5 in terms of political or fiscal ramifications.

An Important Problem Needing a Solution

Plato (in *The Republic*) stated, “Necessity is the mother of invention.” One way to make forecasts is to identify pressing problems faced by large numbers of people, and then to predict that researchers will make progress toward solving these problems. Alternatively, your knowledge of the complexity of the problems may lead you to predicting that little or no progress will occur.

For example, many people and organizations throughout the world agree that AIDS is an important problem. They are devoting a great deal of research and other efforts toward solving the problem. As these efforts began to be ramped up, one could make predictions about their likelihood of success. It seemed to leading medical researchers that the problem could likely be solved—that is, that it was not hopelessly beyond the capabilities of our current medical sciences. It also seemed that the problem was very difficult. Working toward solving it would be pushing the envelop of the science and technology of medicine.

Certainly some progress has occurred over the past decade. However, AIDS has proven to be a much more difficult problem than people first thought it would be. It appears that we are still far from finding a solution to the problem.

This general pattern of identifying a problem and looking for a solution applies in other major problem areas. For example, consider the information explosion. Even in a single research university, there are hundreds of active researchers who are advancing their fields. On a worldwide basis, there are literally millions of researchers who are adding to the totality of human knowledge.

The United States Library of Congress now contains more than 120 million items. Millions of items are added each year. And, this is merely one of the great libraries of the world. It concentrates much of its acquisition efforts on materials written in English. Almost every country has a major library that focuses on materials published in the language(s) of the country. Thus, it is evident that there is a huge amount of collected information and that this worldwide collection is growing rapidly.

The information explosion is not a new problem. Vannevar Bush, Director of the Office of Research and Development, placed a major focus on this problem in a July 1945 report to the president. Technological progress during WW II had been immense. Researchers were being overwhelmed by the amount of accumulated information. Moreover, there were a huge number of researchers and research projects contributing to the ever-increasing collection of information. Clearly, there needed to be an orderly approach to the organization and dissemination of this information. Bush’s report contributed greatly to the eventual formation of the National Science Foundation (NSF) The NSF has proven to be an effective vehicle both for research and for dissemination.

As computers began to come into widespread use, a number of people noted that they could be used for the storage and retrieval of documents. The need to find solutions to the information explosion problem led to an immense amount of research and development in this area. Computerized information storage and retrieval systems have come into routine use. The computerization of contents of major libraries is beginning to occur. In conjunction with the steady growth in the telecommunications infrastructure, this provides a basis for predictions of making the libraries of the world readily available to students. Increasingly, people will not need to “go to the library.” Rather, the contents of the library will come to them—from libraries throughout the world. This megatrend is now well established and is continuing at a rapid pace.

Another example comes from people's insatiable need to communicate with each other. The Walkie Talkie developed during WW II was a predecessor to the cell telephone. During the ensuing decades, progress in ICT led to the development of easily portable and relatively reliable cell telephones. Approximately 400 million cell telephones (equivalent to one for every 15 people on earth) were sold in 2002, approximately 500 million in 2003, and approximately 690 million in 2004. Estimates are that for 2005, approximately 710 million cell phones will be sold worldwide. That is slightly more than one for every nine people on earth.

Expert Opinion from a Person

Consider the following questions:

- What college football team will win the national championship next year?
- What will the inflation rate in this country be during the next 12 months?
- What will the average unemployment rate be in this country during the next 12 months?
- When will a successful vaccine against AIDS become available?
- In the public schools in the United States, what will the average ratio of students per computer be in five years?

For these and many other "prediction" types of questions, many people have opinions. However, some opinions may be worth more than others. Look through the list of questions. Think about your varying levels of expertise in the areas that they represent. Think about how expertise in an area may contribute to credibility (and accuracy) in making forecasts in the area.

For example, there are some people who know a great deal about college football. They are experts in the field. They know the colleges, the coaches, the players, and previous performances. They have spent years developing their expertise, and they work hard to maintain their expertise. Even though predicting the outcome of college football games is by no means an exact science, we expect a highly knowledgeable expert to have a higher level of success than a rank beginner.

There are some acknowledged experts in the field of information and communications technology. Nicholas Negroponte, founding chairman of the Massachusetts Institute of Technology Media Lab, is such a person. The MIT Media Lab is a world leader in exploration of new media technologies, such as intelligent agents and high definition television. In his book *Being Digital* (1995), Negroponte, points out a number of trends and makes a number of forecasts. As is suggested by the title of his book, he is confident that digitization of information will lead to major changes in the societies and institutions of the world. The Website Negroponte (n.d.) contains monthly columns, 1993-1998 from *Wired Magazine* that I have thoroughly enjoyed. Currently, Negroponte is spearheading a project to develop a \$100 laptop computer that would be suitable for education in developing countries. He hopes that these will begin to become available in late 2006 (Siddle, 2005).

An earlier part of this chapter mentions the idea of trend analysis. Alvin Toffler (1980, 1990), with major help from his wife Heidi, has produced a number of books that have analyzed social trends and forecast the future. Toffler's *Powershift: Knowledge, Wealth, and Violence at the Edge of the 21st Century*, focuses on the idea that knowledge is power, and that this is now the most important type of power. The Tofflers contrast this with other types of power such as industrial and military might. They suggest that the power of a nation is dependent on a combination of various types of power such as agricultural power, industrial manufacturing

power, military power, and knowledge (the Information Age technologies). The powershift described in his book represents a major paradigm shift.

Toffler's book that focuses on knowledge as power contains a large number of carefully reasoned arguments to support his contention. A reader can follow the lines of reasoning and analyze the arguments.

Expert Opinion from a Group of People

In certain forecasting areas, it has become common to ask a number of experts, and then to compute an average of their forecasts. For example, each year economic forecasts for the next year are computed in this manner. In recent years a new type of "expert" economic forecaster has arisen. There are now a number of different computer programs that have been developed to do economic forecasting. Such programs draw on modern theories of economics, a huge amount of data on past and current economic performance, and a variety of predictive computations. It turns out that economic forecasting has some of the same difficulties as weather forecasting. It is a challenging problem.

It often happens that experts do not agree with each other. One way to work with a group of experts is a technique called the Delphi Process. This idea is rooted in ancient history.

Dating back to 1400 BC, the Oracle of Delphi was the most important shrine in all Greece, and in theory all Greeks respected its independence. Built around a sacred spring, Delphi was considered to be the omphalos - the center (literally navel) of the world.

People came from all over Greece and beyond to have their questions about the future answered by the Pythia, the priestess of Apollo. And her answers, usually cryptic, could determine the course of everything from when a farmer planted his seedlings, to when an empire declared war (Oracle of Delphi, n.d).

Legends tell us that the Oracle of Delphi was able to predict the future, but it was not easy to interpret the visions that were presented. The Delphi process, named after this oracle, is a method for seeking consensus on expert opinion on the future. In the Delphi process, a group of experts is asked to make forecasts in a particular area and to write brief statements to support their forecasts. For example, the experts might be asked to forecast typical everyday use of computers in schools 10 years in the future. A summary of the results is then shared among the experts, and they are asked if they want to revise their forecasts and their supporting arguments. Through several cycles of a forecasting and sharing of forecasts process, the individuals obtain information about the forecasts made by the group as well as individual arguments for and against various parts of the forecasts. Often a group will reach near consensus after three or four rounds. Quoting from Delphi Method (n.d.):

The technology forecasting studies which eventually led to the development of the Delphi method started in 1944. At that time General Arnold asked Theodor von Karman to prepare a forecast of future technological capabilities that might be of interest to the military (Cornish, 1977). Arnold got the Douglas Aircraft company to establish in 1946 a Project RAND (an acronym for Research and Development) to study the "broad subject of inter-continental warfare other than surface." In 1959 Helmer and fellow RAND researcher Rescher published a paper on "The Epistemology of the Inexact Sciences," which provide a philosophical base for forecasting (Fowles, 1978). The paper argued that in fields that have not yet developed to the point of having scientific laws, the testimony of experts is permissible. The problem is how to use this testimony and, specifically, how to combine the testimony of a number of experts into a single useful statement. The Delphi method recognizes human judgment as legitimate and useful inputs in generating forecasts. Single experts sometimes suffer biases; group meetings suffer from "follow the leader" tendencies and reluctance to abandon previously stated opinions (Gatewood and Gatewood, 1983, Fowles, 1978). In order to overcome these shortcomings the basic notion of the Delphi method, theoretical

assumptions and methodological procedures developed in the 1950s and 1960s at the RAND Corporation. Forecasts about various aspect of the future are often derived through the collation of expert judgment. Dalkey and Helmer developed the method for the collection of judgment for such studies (Gordon and Hayward, 1968).

Change in Social Institutions

Michael Fullan (1991) is one of a number of leading educational researchers who have carefully studied change processes in social institutions, such as education. These researchers look at many hundreds of examples of change—or the lack of change. They attempt to identify conditions and environments that support change. They analyze why many well-funded major attempts to change have failed. They can predict with considerable accuracy whether a particular project will lead to significant and lasting change.

A social system—such as a school, school district, or state educational system—has a level of stability that strongly resists change. As an example, consider a newly hired teacher, fresh out of an excellent teacher education program. This new teacher is a potential change agent, filled with modern theories and concrete ideas for change.

This newly hired teacher is placed in an environment in which the students, the other teachers, the school administrators, and the parents all expect “business as usual.” Almost invariably, the newly hired teacher adjusts to the school, rather than managing to produce significant changes. Keep this in mind if you are a person developing a personal plan for your own future.

The same general difficulty exists for a project designed to make a significant change in some aspect of the school. If the level of resources and the quality of leadership available to the project are sufficiently high, an initial change (hopefully, an improvement) will be produced. However, the level of resources and enthusiasm typically declines after a year or two. Things tend to return to the way they were at the beginning.

As one attempts to forecast change in social systems—including our educational system—the most accurate forecast tends to be one of “no change, business as usual.” However, we do have examples of significant changes that have occurred. At the national level in the United States, Public Law 94-142 mandated changes in the education of people with certain types of handicapping conditions (Public Law 94-142, 1975). Significant changes in our educational system can be traced to this law. This is an example of new policy having a significant effect on the educational system.

Our legal system has made it possible for many people to sue over non-compliance in PL 94-142 cases. Thus, even though the federal government has not come close to fully funding the mandates of the law, state, regional, and local funding agencies have been forced to provide the funding to meet the requirements specified in the law.

One can think of our educational system as a social system. At the current time, politicians are sensing that the will of the people is to improve our educational system. This appears to be a trend that will likely continue well into the future. Choice, alternative schools, Charter Schools, voucher systems, and an increase in home schooling are all part of an emerging trend away from the “business as usual” in our public school system.

Some people compare our educational system with our business and industry system. The past two decades and more have seen major changes in the business and industry workplace.

Examples include a substantial decrease in middle management positions, empowerment of front-line workers, and front-line workers being expected to be much more versatile in the duties they perform. Many companies have downsized. The use of independent contractors and temporary help, and the out-sourcing work that was previously done in-house, have become common. Leaders in the business field who have been involved in such changes look at education and wonder why it is not undergoing similar changes. They argue that education needs to be run more like a business and that competition is healthy.

Such people also point to changes in productivity that have occurred in agriculture and in manufacturing. They wonder why education has not been able to increase productivity. Measures of increased productivity might be achieving current levels of learning with far less personnel and cost, or substantially increasing levels of learning without increasing personnel and costs. Computer-assisted learning and asynchronous distance education are often suggested as a paradigm shift what will lead so such increases in productivity.

Consumer and Business Products

Many products gain widespread acceptance in one market, such as business, before gaining acceptance in a second market, such as the home or school. For example, desktop presentation hardware and software gained considerable acceptance in business before beginning to have a significant impact on education. Television gained considerable acceptance in the home before it began to have a significant impact on education. Computerized information retrieval systems gained considerable acceptance by researchers long before they began to affect K–12 education.

This suggests another way to look for possible changes in information technology in K–12 education. Look at how technology is affecting the home, business, government, or other large groups of people. Identify products that are having a significant impact on one of these groups. Analyze whether the product might be of significant value in K–12 education. This approach would have predicted that handheld calculators would be widely adopted in K–12 education.

However, this method of forecasting needs to take into consideration additional factors. As it turned out, many adults (including many teachers) opposed the use of handheld calculators in schools, even though the adults routinely used calculators themselves. Thus, actually integration of calculators into the everyday school curriculum has occurred quite slowly. Even now, many elementary school teachers strongly resist this integration effort.

I find it interesting that individual teachers seem to be allowed to make this decision about use of calculators in their classrooms. To me, this suggests that within education, major paradigm shifts are not necessarily easily accepted and implement, even though they have been widely accepted outside of education. Many aspects of computers are facing similar reticence on the parts of a large percentage of teachers.

Decisions of Major Businesses

A continuing theme in this book is that one way to accurately predict the future is to create the future. For example, suppose that a major chip manufacturing company is considering the investment of \$2 billion to build a major chip production facility and research center. Such a facility might employ 1,000 production-site people and 500 researchers. Such an influx of relatively well-paid and relatively well-educated workers can have a major impact on a small community. The company can envision such major changes in a community and then cause them to happen.

Consider the specific example of the telecommunications industry. It is both large and continuing to grow rapidly. There is now considerable competition among various types of companies, such as the cable television industry and the telephone industry. There is a major trend of installing fiber optics and of increasing the two-way switching systems that carry high capacity lines into homes and businesses. One can predict with considerable confidence that this megatrend will continue.

The couple of years have seen very rapid increase in the use of Internet-based telephone (and videophone) services. This is now a megatrend that seem likely to continue.

How will growth in telecommunications shape the world? One piece of an answer is already clear. The number of telecommuting workers is steadily growing. A steadily increasing number of jobs can be filled by people who are located thousands of miles from the main offices of the company they work for. This is starting to have a significant impact on world business. We are used to the idea that physical goods might be manufactured in one country and shipped to another. If the manufacturing process is labor intensive, then such manufacturing tends to gravitate to low wage countries.

Now, a similar thing is happening for a variety of knowledge-work types of jobs. As an example, consider computer programmers and researchers in the ICT industries. There are many places in the world where very highly educated and skilled people who can fill such jobs are being prepared. Due to progress in worldwide telecommunications, there is a steadily increasing worldwide competition from applicants to live where they currently are living, but to fill such jobs. This is another example of a megatrend that has begun and will likely grow to very large proportions.

We can expect the same thing to happen for telecommuting students. Distance education can be delivered to people (including children) at a time and place to suit their convenience (at home, at work, at play). This clearly has the potential to affect our conventional factory-model educational system in which instruction is delivered at a fixed time and fixed place. That is, although education has not been a major driving force for improvements in telecommunications, it seems clear that such changes will have a major impact on education.

Plausible Scenario

People often look at science fiction writers as good forecasters of the future. Sometimes a science fiction writer will have solid knowledge of the underlying science in the stories he or she writes. Arthur C. Clarke provides an excellent example. A number of his stories have proven to be relatively accurate portrayals of the future.

Many people who are doing long-range strategic planning make use of scenarios to describe what they think the future will look like. In essence, they write plausible science fiction. This is illustrated in the following scenario written in 1999 and set in the year 2015 (Moursund, 1999).

It is still raining and cloudy early in the morning when Saundri finishes her breakfast and opens her PEA (Personal Education Assistant). Clouds and rain mean the household solar energy system is not producing much power. Today is Saundri's fifteenth birthday, and she is looking forward to a busy and fun-filled day. She hopes the weather will improve so that a lack of electrical power will not interfere with her evening party plans.

Glancing at her PEA, Saundri notices that the wireless connectivity to the Internet is solid at one megabyte per second. The battery level indicator is at the one-third level, indicating that she has about seven hours of power. She will have to charge the batteries later in the day. She also notes that the PEA's free memory is down to twenty-five gigabytes. Soon she will have to do some house cleaning.

With a few voice commands, Saundri sends her previous evening's homework to her various teachers. While doing so, she thinks briefly about her mathematics teacher in London, her science teacher in Washington, DC, and her global studies teacher in Mexico City. It would be neat to someday meet them face to face. Being in secondary school is fun, but she misses the interpersonal contacts of elementary school, where the teachers and students came together each school day.

Next, Saundri checks her computer "Inbox" and sees that she has quite a few e-mail messages, voice phone messages, and videophone messages. Her friends and fellow students from around the world have messaged her because they know it is her birthday. Plus, all of her course instructors have provided feedback on the schoolwork she turned in yesterday. There are other messages from her teammates on several school group projects.

Saundri opens some of the birthday greetings and talks to a couple of her friends. Several of her friends speak and write in languages that Saundri does not know, but her PEA provides reasonable quality translations in real-time. One message contains a gift for two free video viewings. She instructs her PEA to download *Gone with the Wind*, her current all-time favorite. She will share it with her friends and family at the birthday party this evening.

In her courses, Saundri is working on several large projects. In math and science, for example, her project is to explore situations in which research in math has led to new discoveries in science, and situations in which research in science has led to new discoveries in math. She is one member of a four-person team collaborating on this project. Her specific task is to understand what led to the development of the math topics currently being studied in her math course. The intended audience for this team term project are students located throughout the world with an interest in both math and science. The team will publish its report as an interactive World Wide Website, which is designed to help users learn how math and science have benefited each other.

Saundri is working on another project individually. It combines global studies with health education. She is particularly interested in how various levels of education in different countries may be affecting health levels, and vice versa. This project is dear to her heart, because one of her brothers died from a disease when he was only six years old. So, the fifteen-year-old decides to work on this topic for awhile.

She begins to look at death rates due to disease among people worldwide fifteen to thirty years of age as well as the number of years of schooling the deceased achieved. Saundri is searching for possible correlations. This project, however, seems too complex for the correlation techniques she has studied in the past. She asks to speak to her Statistical Consultant, a computer-based "agent." After a brief conversation, the Statistical Consultant senses that Saundri is in over her head and begins to provide her with an interactive tutorial on possible statistical techniques to use in this situation. In addition, the Statistical Consultant suggests that Saundri first study data from just two countries, rather than from the worldwide set of 273. This method will allow her to quickly carry out some trial-and-error experiments to help her more fully define the problem.

Meanwhile, her PEA has combed its own databases and begun a Web search. It reports that its own databases contain baseline data on education in the 273 countries but that the desired health data is scattered over thousands of databases on the Web. Saundri picks two countries for her pilot study and tells her PEA how to set up the database. Her PEA indicates that this task will take a few minutes, because it will have to search seventy-two Websites to get the needed data.

Rather than sit and twiddle her thumbs, the birthday girl asks to speak to her Personal Tutor. Saundri's Personal Tutor is another computer-based agent that works with her as she uses the Intelligent Computer-Assisted Learning (ICAL) materials in her PEA. The tutor immediately appears onscreen and praises her for beginning her schoolwork so early in the morning. Her Personal Tutor has complete records on what Saundri has studied, her interests, her preferred learning styles, and her areas of greatest intelligence from Howard Gardner's most recent list of ten intelligences. Saundri's Personal Tutor and the ICAI system make it possible for her to study anything she wants to study, at any time she wants to study it. The nature and level of instruction is always appropriate to her current knowledge and skills, and the best current theories of teaching and learning are always incorporated.

Later in the day, the sun shines bright and clear. Saundri plugs her PEA into the household solar energy system so it can recharge while she is out for soccer practice. She remembers to give a mental "Thank you!" to UNESCO for providing her with a full scholarship and the PEA for her secondary school education--especially since many of Saundri's friends dropped out of school at age twelve.

The bus into Nairobi will be coming through Saundri's village in a few minutes, and she is looking forward to this afternoon's workout with the soccer team. However, she will have to be on time getting back to her village, because she has a music lesson just before supper.

Does Saundri's scenario from the year 2015 sound like science fiction? Or does the technology-assisted education of this fifteen-year-old girl from Kenya seem like a plausible picture of the future? Remember, this scenario was published in 1999. Think about how much "progress" has already occurred toward achieving the type of world pictured in the scenario.

About a half year ago, I was asked to write a futuristic scenario for a meeting of ICT in education leaders. The people in charge of this meeting indicated that most of the ideas in the year 2015 scenario had already been achieved, and that a much more "far out" scenario was needed. It is correct that the year 2015 scenario is now technically feasible. However, it has not yet been widely implemented. It represents a paradigm shift in education that is slowly occurring, and that might be moderately widely in place by 2015.

Concluding Remarks

Forecasters have a number of tools at their disposal. When there is solid underlying theory in the areas to be forecast (such as an eclipse of the sun), we can expect a high level of accuracy in the forecasts.

An eclipse of the sun is a very simple phenomenon as compared to next month's weather, next year's economy, or the interests of consumers 10 years from now. Thus, we must view with caution long-range forecasts in such areas as economics, consumer-buying patterns, and in other areas that depend on individual choices of large numbers of people.

This caution certainly applies to forecasts in education. Our educational system sets goals and then allocates resources toward achieving these goals. In some cases the allocation of resources is sufficient to cause the goals to be achieved—in essence, the future is constructed. However, our educational system is vast and complex. The resources available to facilitate change are relatively limited. There are multiple demands on these resources. Many different futures are possible, and it is quite difficult to predict what our educational systems will look like a few decades from now.

As an example of difficulties in educational forecasting, relatively few people seem to be willing to talk about progress in developing drugs that significantly enhance the speed of learning and the performance of the human mind. There is considerable research money being invested in these areas, partly because of how they relate to Alzheimer's and other problems of the aging.

Personal Growth Activities for Chapter 5

1. Spend some time viewing your world through "forecaster-colored glasses." For example, you get up in the morning and think about the day that lies ahead of you. You "forecast" what you will be doing during the day. Perhaps you will be attending a meeting with some of your colleagues. You forecast what this meeting will be like. You may make a plan to behave differently than usual in this meeting. You think about what might happen if you are more vocal and forthright. (You make a plan and forecast the possible results.)

Think about the extent to which you consider the consequences of your actions before you take the actions. Considering the consequences of possible actions is a type of forecasting/planning activity.

Activities for Chapter 5

1. Analyze the process of developing a lesson plan, teaching following the plan, and assessing the outcomes from the point of view of planning and forecasting. For example, before you actually begin teaching from a lesson plan, you have forecast how the overall teaching process will likely go and the learning outcomes that will be achieved. Your analysis might include a discussion of how accurate you are at such forecasting.
2. Select an area in which you commonly make forecasts. Describe how you go about making these forecasts and the accuracy of your results. Which, if any, of the forecasting methodologies described in this chapter do you use?
3. To what extent do you depend on forecasts made by others? As a simple example, if the weather forecaster forecasts rain later in the day, do you carry an umbrella? Make a list of some of the forecasts that you do and/or do not pay attention to, and analyze your behavior.
4. Think about the current situation of voice input to computers. Make a forecast for voice input by students at school and at home. Explain your forecasting methodologies, based on the variety of methodologies described in this chapter.

Chapter 6: The Future, Writ Large

We'll see 1,000 times more technological progress in the 21st century than we saw in the 20th. (Ray Kurzweil. PC Expo in June, 2000)

The illiterate of the 21st century will not be the one who can not read and write, but the one who can not learn, unlearn, and relearn. (Alvin Toffler)

This chapter contains some very general forecasts for the future that are relevant to the field of education. The unifying theme is increasing productivity by progress in science and technology that provides aids to accomplishing physical and mental activities.

The previous sentence is certainly a mouthful. Figure 6.1 is the same as Figure 2.1 given in chapter 2. The general idea represented in Figure 6.1 is that the human race is making continual progress in developing physical body and mental aids that have the potential to increase the productivity of a person or a team of people. Appropriate formal and informal education underlies the effective use of these aids to solving problems and accomplishing tasks. Thus, overall progress in increasing productivity depends on a combination of progress in science, progress in technology, and progress in education.

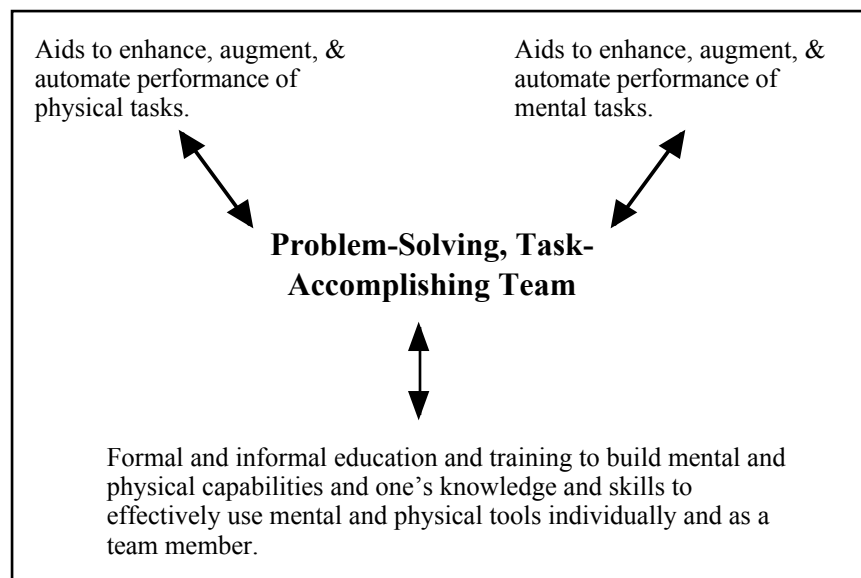


Figure 6.1. Aids to performance of physical and mental tasks.

Productivity

Peter Drucker is perhaps the leading business management consultant and business futurist of the 20th century. The following short quote from Peter Drucker is from a presentation to some members of the US Congress in the winter of 1992 (Drucker, 1992).

Productivity [in manufacturing and agriculture in the United States] has increased 50-fold in the last century ... and is growing as fast as ever. [Now] both sectors together employ fewer than one-sixth of the labor force. [...]

How has it been possible to increase agricultural and manufacturing productivity by a factor of 50? In essence, one can answer the question by looking at how scientific research and technological progress have been combined during the Industrial Age.

For example, think about a farmer plowing a field using a team of horses or oxen, and then planting and harvesting using similar tools. Compare this situation with a farmer using a 300 horsepower air-conditioned tractor for plowing, applying appropriate amounts of fertilizer, using the best of highly productive and disease resistant hybrid seeds, a planter (perhaps draw by the tractor), and a harvester (perhaps with its own built-in power system). It is easy to see how the productivity of a farm worker increased by a factor of 50.

A similar analysis can be done for industrial manufacturing. The increase in agricultural and manufacturing productivity substantially raised the average standard of living. At the same time, it substantially changed employment. Remember, at the time of the American Revolution (about 230 years ago), about 90% of the people worked on farms and the Industrial Age had not yet started. Thus, in the US the past 230 years or so have seen the end of the Agricultural Age, the beginning and end of the Industrial Age, and roughly the first 50 years of the Information Age.

Nicholas Negroponte is a professor of media technology at the Massachusetts Institute of Technology and founding chairman of MIT's Media Laboratory. Negroponte's writings and the work of the MIT Media Laboratory are good sources of forecasts for the Information Age (MIT Media Lab). Quoting from Negroponte's book *Being Digital* (Negroponte, 1995, pp11-12):

The best way to appreciate the merits and consequences of being digital is to reflect on the difference between bits and atoms. While we are undoubtedly in an information age, most information is delivered to us in the form of atoms: newspapers, magazines, and books (like this one). Our economy may be moving toward an information economy, but we measure trade and we write our balance sheets with atoms in mind. GATT is about atoms.

...

The information superhighway is about the global movement of weightless bits at the speed of light. As one industry after another looks at itself in the mirror and asks about its future in a digital world, that future is driven almost 100 percent by the ability of that company's product or services to be rendered in digital form. If you make cashmere sweaters or Chinese food, it will be a long time before we can convert them to bits. "Beam me up, Scotty" is a wonderful dream, but not likely to come true for several centuries. Until then you will have to rely on FedEx, bicycles, and sneakers to get your atoms from one place to another. This is not to say that digital technologies will be of no help in design, manufacturing, marketing, and management of atom-based businesses. I am only saying that the core business won't change and your product won't have bits standing in for atoms.

Drucker and Negroponte both envision a future driven by the production, storage, transmission, and use of digitized information. The following quote is from Drucker (1993, page 194):

A technological revolution—desktop computers and satellite transmission directly into the classroom—is engulfing our schools. It will transform the way we learn and the way we teach within a few decades. It will change the economics of education. From being totally labor-intensive, schools will become highly capital-intensive.

But more drastic still—though rarely discussed as yet—will be the changes in the social position and role of the school.

Though long a central institution, it [the school] has been "of society" rather than "in society." It concerned itself with the young, who were not yet citizens, not yet responsible, not yet in the work force. In the knowledge society, the school becomes the institution of the adults as well, and

especially of highly schooled adults. Above all, in the knowledge society, the school becomes accountable for performance and results.

In this statement, Drucker makes two sweeping forecasts for education:

1. Education will change from being labor intensive to being capital intensive.
2. In the knowledge society, schooling will become a lifelong endeavor, and schools will become accountable for performance and results.

The first of these two forecast is based on an understanding of the sweeping changes that the Industrial Age brought to agriculture and manufacturing. In essence, the Industrial Age brought us very powerful aids to our physical body performance. Drucker understands that ICT is bringing us very powerful aids to our mental performance. He reasons that since Industrial Age science and technology transformed agriculture and manufacturing, then Information Age science and technology will transform education.

The second of the two forecasts is based on insights into changing **needs** of people and changing **demands** of people. To function well in a rapidly changing Information Age society, people **need** lifelong schooling. Our increasingly educated citizens **demand** that the products and services they pay for and use be of appropriate quality. Increasingly, they will hold our lifelong schooling system **accountable** for its performance and results.

These two forecasts by Drucker help to focus and unify the remainder of this book. Thus, you should think carefully about these two forecasts. Do you believe that they might prove to be reasonably accurate? Will you spend your professional career in education working to help these forecasts come true? Or, perhaps you will spend your professional career working to prevent one or both of these forecasts from becoming true. In either case, you will be working on inventing your specific future in education and contributing to the future of education.

Needs for a Significant Change in Education

Many people are critical of our current educational system. Indeed, it is quite easy for a stakeholder group or an individual person such as a parent to find fault. However, it is not so easy to understand the sweeping changes going on in the societies of the world, and then translate them into need for corresponding sweeping changes in our educational system.

From Drucker's point of view, we must look for ways to increase the productivity of our educational system. Increased productivity means an appropriate combination of three things:

1. That students learn better (for example, with increased understanding) and faster.
2. That the content of what students learn is improved so that it more appropriate to being a productive citizen and responsible adult in our Information Age society.
3. That the educational system should become more accountable for its performance and results as it accomplishes 1 and 2 with fewer employees and/or with less labor costs.

The next three subsections contain brief discussions of these three components of increased productivity.

1. Students Learn Better and Faster

We know that under proper circumstances, students can learn better and faster. Benjamin Bloom's work suggests that individual tutoring by an appropriately qualified tutor can move a

typical “C” student to the level of an “A” student (Bloom, 1964). Some of the other researcher-based findings in education include:

- Research in special education has given us good insight into the value of individualizing education and focusing on meeting the needs of the learner.
- Research on “good” teachers versus “poor” teachers suggests that students who have “good” teachers learn better and faster.
- Research on computer-assisted learning suggests that CAL can be a significant aid to helping students learn better and faster (Kulik, 1994).
- We also have increased understanding of the value of letting the learner plan an increasing role in deciding on the content to be learned. Evidence of this comes from research in adult education and from research in project-based learning (Moursund, PBL, n.d.).

It is also important to note that our current precollege system does not do well in meeting the needs of Talented and Gifted students. These students are able to learn much faster and better than average students.

Personal note added 5/22/05: During the past year I have been particularly interested in Talented and Gifted (TAG) education. In addition, I am interested in how fast students learn, and in ways of speeding up rates of learning.

As far as I can determine from looking at a lot of research literature, TAG students are able to learn perhaps two to three times as fast as average students. The research into Computer-Assisted Learning has explored gains in rate of learning. A standardly quoted figure is that over lots of studies in CAL, average rate of learning gains have been about 30%.

I have not found data that is specific about the increase in rate of learning that comes from individual tutoring. However, a variety of “educational interventions” are based on having individual tutoring or very small classes. Success in such interventions tends to be based on students achieving a relatively high rate of learning (catching up with their classmates) and increased quality learning.

We are beginning to see some examples of intensive educational interventions making use of research-based Highly Interactive Intelligent Computer-Assisted Learning. In certain cases, the gain in rate of learning exceeds that which is being achieved in individual tutoring.

Remember, once such a level of success is achieved in a particular small educational problem area, two things are apt to happen:

1. The educational intervention is apt to be widely used.
2. The ideas that worked in the intervention are apt to be tried in lots of other education problem areas, and more researchers developers are apt to apply their efforts in expanding the range of use of the new ideas.

Based upon this type of analysis, I forecast substantial improvements in our educational system over the next couple of decades.

In brief summary, good teachers, small classes, and individualization tend to lead to significant improvements in how well and how fast students learn. In the past, such conditions for learning have been created by labor-intensive approaches, such as hiring more teachers and requiring that teachers have more education and experience. A significant change to implementing such changes through the use of ICT (for example, through the use of asynchronous distance learning and highly-interactive computer-assisted learning) would represent a large paradigm shift in education.

2. Improved, More Appropriate Content

We are used to the idea that the content of school curriculum changes over time. However, content changes tend to be slow. Thus, there tends to be a substantial lag between the content that is actually taught and what might be called “modern, up to date” curriculum content.

Mass media has helped some in changing this situation. Mass media tends to expose students and their teachers to a wide range of relatively current events. The Web can be viewed as a new form of mass media—a form of narrowcasting. There is a clear trend toward increased use of this somewhat individualized form of mass media and away from broadcast radio and television.

Right now we are seeing a significantly increased focus on problem solving and other higher-order cognitive skills. There is increasing understanding of a need to change the balance (established in the past) between education via rote memory and education for understanding and for creative problem solving. State and national assessments are placing more emphasis on such higher-order cognitive performance.

Right now, a great deal of our school time is spent teaching students to do things that computers can do quite well. In essence, we are educating students to compete with computers. However, there is a slowly growing understanding that education needs to prepare students to work with mental tools, rather than to compete with them.

Over the past couple of decades, I have been surprised that our educational system has been so resistant to such change. Being the optimist that I am, I predict the next couple of decades will see a significant paradigm shift in this area. We will provide students with powerful aids to solving challenging problems and accomplishing challenging tasks. We will educate students to live and work in environments where such aids are routinely available.

3. Increased Accountability and Productivity

The past decade and more has seen a steady increased emphasis on accountability in our schooling system, especially at the precollege level. The No Child Left Behind legislation of January 2002 has a strong focus on increased accountability (NCLB, n.d.). While many people support increased accountability, there is less agreement on what constitutes increased, appropriate accountability.

One of the major challenges here is that while it is relatively easy to measure productivity in agriculture and manufacturing, it is difficult to measure productivity in education. This challenge tends to lead us in setting some quite narrow measures of productivity. For example, we are using scores on widely used tests as a measure of productivity. However, a score on a test is not like food on the table (agricultural productivity) or a color television set in the living room (manufacturing productivity). A decision to use test scores as a measure of productivity moves productivity efforts toward increasing test scores. We know how to improve test scores by teaching students to be better at taking test and by giving them lots of practice in taking tests. Such an approach completely misses the goal of students getting a better education!

There are a variety of methods currently being used decrease labor costs of education. For example, many institutions of higher education are now making use of a multi-tiered teaching force (differentiated staffing). This might consist of tenure track or tenured faculty, adjunct, temporary, and other variations on lower cost non-tenure track faculty, teaching assistants and hourly help. For the most part, these approaches do not decrease the total workforce. Instead, they cut the overall cost of this workforce.

A somewhat similar approach is sometimes used in precollege education. In some places, a teacher's aide or a certified staff member costs approximately one-fourth to one-third as much per hour as a fully certified teacher. Appropriate use of such aides and certified staff can decrease the overall personnel costs in a school. Somewhat similarly, many schools are finding that contracting outside of the school or school system for a variety of services (for example, janitorial services) decreases costs.

Still another approach lies in improving the educational value of and use of materials that can be mass distributed, such as TV, radio, viewing DVDs, CDs video and audio tape, tapes, books and other print materials. People of all ages learn from such media. Sesame Street provides a good example of TV that has aided early childhood education, and it is not labor intensive.

We are now living during a time of steady increase in the quality and quantity of interactive hypermedia versions of the types of distribution systems mentioned in the previous paragraph. Such aids to learning are more capital intensive and less labor intensive than other ways to improve education.

The topic of increased productivity of the education labor force (and/or decreased cost of this labor force) is daunting. Among other things, our precollege education system provides a "safe place" and care away from home for children. Such childcare (quite independently of education provided during this childcare time) is labor intensive and relatively expensive. Thus, it is not at all obvious how schools can become more productive from a labor point of view.

Peter Drucker does not pretend to have a solution to the problems faced by our education system. He recognizes the complexity and challenge of the task, and he certainly has some suggestions of what needs to be done (Drucker 1993, page 197).

So far, no country has the educational system which the knowledge society needs. No country has tackled the major demands. No one knows the "the answers"; no one can do what is needed. But we can at least ask the questions. We can define—albeit in rough outline—the specifications for schooling and for schools which might answer to the realities of the post-capitalist society, the knowledge society.

Here are the new specifications:

- The school we need has to provide universal literacy of high order—well beyond what "literacy" means today.
- It has to imbue students on all levels and of all age with a motivation to learn and with the discipline of continuing learning.
- It has to be an open system, accessible both to highly educated people and to people who for whatever reason did not gain access to advanced education in their early years.
- It has to impart knowledge both as substance and as process—what the Germans differentiate as *Wissen* and *Können*.
- Finally, schooling can no longer be a monopoly of the schools. Education in the post-capitalist society has to permeate the entire society. Employing organizations of all kinds—businesses, government agencies, non-profits—must become institutions of learning and teaching as well. Schools, increasingly, must work in partnership with employers and employing organizations.

The Future of ICT

In this section we will explore the future of three aspects of ICT: 1) Hardware; 2) Software; and Theory (the science underlying and supporting the technologies of hardware and software).

The forecast is one of ICT systems (combinations of hardware and software) becoming better and even more ubiquitous. The science to support such continued improvement exists and/or is

being developed at a sufficient pace to support a continued rapid pace of change in hardware and software. Progress in ICT will support a steady increase in the nature and extent of automation of aids to physical and mental performance.

There is a long history of research to improve education. During the past 25 years, the field of Brain Science has grown quite rapidly aided by a wide range of non invasive brain scanning equipment, the human genome project, more powerful computers, and more research money. This past weekend I attended a Brain Science Workshop that focused on brain plasticity, with a strong emphasis on how this ties in with education. The Brain Science research is now beginning to make a significant contribution to the overall field of educational research. In some cases, this research is merely validating things that we have “known” or felt we knew, but in other cases it is supporting a much-improved understanding of the teaching and learning processes.

Hardware

There were only about 20 electronic digital computers in the world by the end of 1950. The first mass production of computers in the United States began in 1951, with the production of the UNIVAC I. Its processing speed was 0.525 milliseconds for addition or subtraction, 2.15 milliseconds for multiplication and 3.9 milliseconds for division. A total of 46 of these machines were built over a period of several years. (UNIVAC I, n.d.). Today’s microcomputers are about 10 million times as fast as the UNIVAC I. If we take into consideration the cost, we see that in terms of raw speed, today’s microcomputers are more than a billion times as cost effective as the UNIVAC I.

As the following discussion of other computer hardware components indicates, there have been tremendous improvements in other hardware components of a computer system. In each of these examples, we look back less than 30 years.

- 1. Disk storage.** It was possible to buy a floppy disk drive and floppy disks that worked with the 1976 microcomputers (Bellis, Floppy Disk, n.d.). At that time a floppy disk had a storage capacity of about 100 kilobytes (about 100,000 bytes). Although hard drives existed, they were far more costly than a microcomputer and were designed for mainframe and mini computers. Nowadays, the price of a microcomputer includes a hard drive with a storage capacity of perhaps 80 to 100 gigabytes (a gigabyte is approximately a million kilobytes, or a billion bytes). Thus, disk storage on a microcomputer has gone up by a factor of about 80,000 to 1,000,000 as of the year 2005, and will likely go up by another factor of four by the year 2008. In the first half of 2003 the price of disk memory declined to the \$1 per gigabyte level. Thus, for example, it became possible to buy a 160-gigabyte hard drive for about \$160.
- 2. Fast memory.** By 1976, memory made using chips technology had been available for many years. However, it was still quite expensive. Thus, early microcomputers had 16 kilobytes, or perhaps 64 kilobytes of high-speed internal memory. Nowadays, a medium priced microcomputer might have 256 megabytes of high-speed internal memory (approximately 256 million bytes). Thus, internal high-speed memory has increased by a factor of between 32,000 and 128,000, and will likely go up by another factor of four by the year 2008.
- 3. Connectivity.** Time shared computing was developed more than ten years earlier than microcomputers. The most widely used terminal for connecting to a time shared system was a Teletype machine, and the connect speed was typically 30 (upper case, only) characters per second (300 baud). Early microcomputers did not come with a modem.

However, soon people began to build modems from kits and/or to purchase modems for their microcomputers. Nowadays, a medium priced microcomputer comes with a 56 Kilobaud modem that is about 190 times as fast as the early microcomputer modems. This speed of connectivity can be achieved over ordinary (good quality) telephone lines. For extra money one can get a much higher bandwidth connection into their home or place of work. In recent years, the amount of bandwidth one can purchase for a given amount of money has been doubling in well under 12 months. This pace of change may well continue for a number of more years.

4. **Internet.** Significant progress was occurring in the development of the Internet by the time microcomputers first became commercially available. The goal was to link a number of major computer centers using dedicated high-speed leased telephone lines. This early connectivity allowed the exchange of software and computer data—and it also allowed the exchange of what we now call email messages. We are now well started on changing from Internet 1 to Internet 2. Internet 2 is about 1,000 times as fast as Internet 1. We can expect steady process on this changeover during the next decade (Abilene, n.d.).
5. **Web.** The World Wide Web was not developed until many years after the Internet. It wasn't until the mid 1990s that the Web came into widespread use. Today's microcomputer user expects to have email and Web access. The total content of the Web is continuing to grow quite rapidly, and it seems clear that this trend will continue for many years into the future.
6. **Supercomputers.** Supercomputers are the fastest of the fastest. In the “good old days” supercomputers were mainframe computers with the fastest possible central processing unit (CPU), lots of memory, and employing other state of the art design technology to produce high speed. Then came the idea of using multiple CPUs. Then came the idea of hooking together a large number of microcomputers. The following news item is about the next design of the generation of supercomputers.

Jan 15, 1:14 PM (ET) Accessed 1/16/04:

<http://apnews.excite.com/article/20040115/D803DGQO0.html>. Not available when accessed 5/27/05.

LOS ALAMOS, N.M. (AP) - Scientists at Los Alamos National Laboratory are trying to predict how supercomputers of the future will perform.

The research arm of the Department of Defense has awarded a three-year, \$4.2 million grant for the lab's computer and computational sciences division to performance analysis and modeling, create software tools and evaluate networks.

The defense agency wants to develop by 2008 the optimal design for the next generation of machines, which will be capable of sustained performance greater than 1 quadrillion operations per second, or one petaflop. [Note added by Moursund: The number words go: thousand, million, billion, trillion, quadrillion. A quadrillion is a million times a billion.]

7. **Grid Computing.** Another approach to providing people and organizations with the compute power they need is to make use of computer networks in a methodology called grid computing (Grid Computing, n.d.).

The Grid Computing Information Centre aims to promote the development and advancement of technologies that provide seamless and scalable access to wide-area distributed resources. Computational Grids enable the sharing, selection, and aggregation of a wide variety of geographically distributed computational resources (such as supercomputers, compute clusters, storage systems, data sources, instruments, people) and presents them as a single, unified resource for solving large-scale compute and data intensive computing applications (e.g, molecular

modelling for drug design, brain activity analysis, and high energy physics). This idea is analogous to electric power network (grid) where power generators are distributed, but the users are able to access electric power without bothering about the source of energy and its location.

Quoting from <http://www.grid.org/home.htm> accessed on 5/22/05:

Grid.org is a single destination site for large-scale, non-profit research projects of global significance. With the participation of over 3 million devices worldwide, grid.org projects like [Cancer Research](#), [Anthrax Research](#), [Smallpox Research](#) and the new [Human Proteome Folding Project](#) (running in conjunction with IBM's new World Community Grid) have achieved record levels of processing speed and success.

Three million microcomputers all working together produce about six times the compute power of the fastest supercomputer that is projected to become available three or more years from now.

In summary, the pace of change of ICT hardware has been very fast indeed, and this pace of change seems likely to continue at least for another decade or two. Perhaps you have personal experience with this pace of change. If you bought a microcomputer when you were entering the 9th grade, then by the time you were in the 12th your machine was only about 1/4 as fast as the machines people were currently buying. The same situation holds if you bought a new microcomputer when you entered college and were still were using it during your senior year in college.

Software

The microcomputers of the late 1970s could be programmed in machine language and in BASIC, a programming language that had first been developed for use by college students on time-shared mainframe computers. Eventually, simple word processors and games became available. It wasn't until 1979 that the first spreadsheet software became available (Bellis). Nowadays one can get a wide range of programming languages, applications software tools, and games for a microcomputer. Progress continues to occur in the development of microcomputer software. However, from the point of view of most computer users, the pace of change is now relatively slow.

For example, suppose that you are a writer. I had a friend back in the early 1970s who decided to write a "desktop publish" book using the text processing software available on a minicomputer. He kept track of the time it took, and compared it to his previous writing efforts in which he made use of a secretary. He estimated that his productivity decreased by a factor of five! That is, the hardware and software available at that time were not powerful aids to increased productivity in writing.

This situation changed markedly once good word processing and desktop publishing software became available. I now am quite comfortable composing using a word processor, and doing the layout and desktop publication for my documents. I use a spelling checker, grammar checker, dictionary, and thesaurus that are built into my word processor. I use computer graphics software, graphing software, and a spreadsheet as part of the overall process. The power of these aids to writing have increased my productivity, and I have not made use of a typist for many years.

My older daughter worked as a programmer for Microsoft for a number of years. About five years ago she estimated that programmer productivity had increased by a factor of 10 during the previous decade. However, much of this productivity is going into writing far more complex programs that programmers attempted in the past.

It is obvious to most computer users that computer systems “crash” relatively often. Most often such crashes are due to software bugs. The software industry is working hard to address this problem. However, we can expect only modest progress in the next decade.

The reason for this lies in the complexity of the tasks that programmers are undertaking. They are undertaking more and more challenging tasks and they are faced by steadily changing requirements. Contrast this with the field of civil engineering, where people are faced by the task of designing a good bridge. A good bridge has characteristics such as not falling down and lasting for many years. It takes civil engineers about five “generations” of a new product to produce a good, stable, high quality product.

We have all gotten used to the idea of software containing bugs and how to live with unexplained software crashes. In some sense, computer users are guinea pigs who pay money and use their own time to acquit buggy software that gradually, over a long period of time, is improved.

In brief summary, what software engineers are trying to do is to automate or partially automate more and more complex aspects of human mental and physical activities. They will continue to make significant progress in this endeavor, and we will continue to acquire and make use of buggy software.

Theory

There are huge annual expenditures on both the underlying science of ICT and the technology itself. Historically, good examples can be found in the development of the transistor, first produced in 1947, and later in the development of integrated circuitry and large scale integrated circuitry.

A glimpse into the breadth and depth of the research is provided by taking a look at the Reference section of a 2001 MIT Media Laboratory proposal to the National Science Foundation. The NSF funded this proposal, creating the Center for Bits and Atoms. The proposal included a Reference section containing well over 150 citations. The following is quoted from a November 14, 2003 Executive Summary of the project (Bits and Atoms, n.d.):

MIT's Center for Bits and Atoms is an ambitious interdisciplinary initiative that is looking beyond the end of the Digital Revolution to ask how a functional description of a system can be embodied in, and abstracted from, a physical form. These simple, profound questions date back to the beginning of modern manufacturing, and before that to the origins of natural science, but they have revolutionary new implications that follow from the recognition of the computational universality of physical systems. We can no longer afford to ignore nature's capabilities that have been neglected by conventional digital logic; it is at this boundary between the content of information and its physical representation that many of science's greatest technological, economic, and social obstacles and opportunities lie.

CBA was founded by Profs. Isaac Chuang, Neil Gershenfeld, Joseph Jacobson, and Scott Manalis, with Marvin Minsky. It was launched by a National Science Foundation award in 2001 [1] that is supporting the creation of a unique shared experimental resource that enables the creation of form and function across nine orders of magnitude in length scales [2], as well as an associated intellectual community drawn from across MIT's campus [3] spanning the historical divisions that have emerged between the study of computer science and physical science, and between the development of software and hardware. CBA's government funding is complemented by corporate sponsorship for technology development and transfer [4].

We conclude this section with a brief introduction to nanotechnology (Nanoworld, n.d.). Progress in nanotechnology is key to continued progress in developing more powerful and less expensive ICT systems. At the current time, governments and industry in many countries

throughout the world are expending large amounts of resources for research and development in nanotechnology (Institute of Nanotechnology, n.d.).

Nanotechnology-What is it?

Nanotechnology can best be considered as a 'catch-all' description of activities at the level of atoms and molecules that have applications in the real world. A nanometre is a billionth of a metre, that is, about 1/80,000 of the diameter of a human hair, or 10 times the diameter of a hydrogen atom.

An early promoter of the industrial applications of nanotechnology, Albert Franks, defined it as 'that area of science and technology where dimensions and tolerances in the range of 0.1nm to 100 nm play a critical role'. It encompasses precision engineering as well as electronics; electromechanical systems (eg 'lab-on-a-chip' devices) as well as mainstream biomedical applications in areas as diverse as gene therapy, drug delivery and novel drug discovery techniques.

The US Federal Government is investing heavily in nanotechnology. Quoting President's Committee of Advisors on Science and Technology (PCAST, May 18, 2005):

Today, the United States is the acknowledged leader in nanotechnology R&D. The approximately \$1 billion annual Federal Government funding for nanotechnology R&D is roughly one-quarter of the current global investment by all nations. Total annual U.S. R&D spending (Federal, State, and private) now stands at approximately \$3 billion, one-third of the approximately \$9 billion in total worldwide spending by the public and private sectors. In addition, the United States leads in the number of start-up companies based on nanotechnology, and in research output as measured by patents and publications. Our leadership position, however, is under increasing competitive pressure from other nations as they ramp up their own programs.

...

Education. The future economic prosperity of the United States will depend on a workforce that both is large enough and has the necessary skills to meet the challenges posed by global competition. This will be especially important in enabling the United States to maintain its leadership role in nanotechnology and in the industries that will use it. The NNI has launched a range of education-related programs appropriate for classrooms at all levels and across the country, along with other programs that are aimed at the broader public. While the NNI cannot be expected to solve the Nation's science education problems single handedly, the NNAP members believe that these NNI activities can help improve science education and attract more bright young minds into careers in science and engineering.

Employment

You are undoubtedly aware of the ideas of telecommuting. Telecommuting refers to the idea of working at home, using ICT to facilitate your work efforts. The last decade and more has seen a steady increase in telecommuting, and this trend seems likely to continue.

You are also aware of the idea of "exporting" jobs. For a number of decades US manufacturers have competed with manufacturers in other countries. This has led to US investments in manufacturing facilities in other countries and to US countries contracting for manufacturing to be done in other countries. This situation is often described as one of exporting jobs.

In recent years, there has been a steady increase in exporting relatively high level, Information Age jobs. For example, well qualified computer engineers and computer programmers in India can be hired for a modest fraction of what similarly qualified employees cost in the US. In essence, such employees produce bits—information that can be transmitted electronically. The following quoted materials capture the essence of this situation (Automation Access, n.d.):

Employment

The technology employment picture has been completely transformed by the Internet. The large number of corporate jobs that used to absorb entry level tech workers are being exported to India, Russia, Poland, and other places with high education and low pay—and those jobs aren't coming back. The bigger the company, the more jobs they'll be exporting. Most manufacturing and assembly work has already been sent to the Orient.

Highly skilled jobs remain, and pay well, because basic design, prototyping and pilot production will still be done here, but even if you have skills, there are problems getting hired. Human Resources departments haven't one clue in Hell how to evaluate skilled technical workers. They try to match exact experience and training to exact job requirements, and demand 3 years experience for specialties that have only existed for 18 months. Thousands of technical jobs go unfilled, while thousands who could do those jobs are asking, "Do you want fries with that?"

If you're over 40, the technology employment picture becomes really grim. You have abilities far beyond a 28 year old's, but he's the one that's going to get hired. For over 40s, there are many opportunities in consulting, especially in small and medium business, but that takes social skills and above all, selling skills, exactly what many chose technical careers to avoid.

As a preservice or inservice teacher you might ask, "I wonder what aspects of a teacher's job can be carried out by telecommuting an/or exported?" Chapter 8 helps to answer this question.

Competition in Education

If we look at high quality doctoral programs in this country, we see that there is substantial competition in recruiting good students and faculty. Put slightly differently, good students have a choice of where they will do their doctoral work, and they have some tendency to pick the best programs. The same concept holds for faculty. Quite a bit of this competition for students and faculty occurs on a worldwide basis.

The same type of analysis can be done for students in master's degree programs and for students in undergraduate programs. If we view students as customers of a college or university, then there is competition for these customers. Over the past century, improvements in transportation systems throughout the world have contributed to competition for customers (students) in higher education. Distance education (discussed in chapter 8) is another approach to increasing competition for students.

Ever since the start of public schools, there has been some competition for students at the precollege level. For example, there are public and private schools. Gradually, we are seeing an increase in competition for precollege students. For example, we now have:

1. The "traditional" public school system.
2. A wide range of alternative and "magnet" public schools, typically intermingled in a public school system.
3. Distance education courses available to public school students, and distance education-based public schools.
4. Charter schools, including some distance education charter schools. Charter schools are public schools and typically intermingled in a public school system.
5. Private schools (that may make use of some or a lot of distance education). Sometimes private schooling is paid for by public money through a variety of voucher systems.
6. Home schools.

Each of these schooling designs has certain advantages and certain disadvantages from the consumer (the student) and from various other stakeholder points of view. According to general theories of consumer satisfaction, we can expect that stakeholders such as students and parents are apt to gain increased satisfaction with schooling through having choice. But, consider the level of satisfaction of the stakeholder group that we call politicians or public officials who are concerned with accountability. One of the key characteristics of a charter school is that it is freed from much of the bureaucratic rules and regulations that govern other public schools.

Recent years have seen the development of some interesting developments in the above list. For example, Huerta and González (2004) reports on a significant home school movement that is drawing heavily on distance learning and other aspects of ICT. A steadily increasing percentage of parents have some a college degree or a significant amount of college education. Thus, an increasing number of parents have a level of education that supports home schooling. The Web makes a huge, steadily growing, and up to date library available to home schooled students. Computer-assisted learning and distance learning are making available more instruction that can be delivered directly to a home-schooled student. ICT facilitates communication among parents who want to home school their children—for example, communication to develop and implement support groups and sharing of the parents’ intellectual resources. Finally, ICT is facilitating more telecommuting, which means that more parents can work from home. This analysis suggests that home schooling is apt to continue to grow in the future.

Just for the fun of it, let me carry this analysis one step further. Public schools have a major child care function. There is an economy of scale in the way a public school combines a range of instructional, childcare, and other activities. Now, imagine that ICT continues to make substantial progress in the area of Computer-Assisted Learning and Distance Learning. Suppose that you are a parent who wants to home school his or her children, and that you put together a small group of parents who want to do the same thing. Your group contracts with a charter cyber school to provide all of the coursework and coursework materials that your students will need. In return, the charter cyber school agrees to pay you a significant amount of money for fulfilling the childcare aspects of your child’s education. A very simple-minded budget for such cyber and home school charter school arrangement is given in Figure 6.2. In a typical elementary school charter school, the school receives 80% of the public funding of other public schools. The budget given in Figure 6.2 is for an elementary school.

Cyber and Home School Charter Elementary School Per Pupil Budget	
Income from school district or state	\$5,300
Expenses	
ICT software licenses	\$600
Other instructional materials	\$600
Administrative costs of organization running the Charter School	\$1,700
Home ICT costs	\$700
Payment to parents doing the home schooling	\$1,700
Total Expenses	\$5,300

Figure 6.2. Hypothetical budget for a cyber and home school charter school.

This budget was designed to suggest that we may be at the beginning of a significant change in the nature of home schooling. It includes \$700 a year for a computer and computer connectivity in the student's home. It includes a yearly payment of \$1,700 to the parents who are doing the home schooling.

Concluding Remarks

This chapter begins with a forecast by Ray Kurzweil, a brilliant computer scientist and computer technologist: "We'll see 1,000 times more technological progress in the 21st century than we saw in the 20th." A unifying theme in this chapter is the idea of increasing productivity by investments in tools that help to automate human physical and mental activity. The chapter includes a major focus on the idea of bits versus atoms. ICT has made tremendous contributions to the development of aids to the performance of mental tasks, and we can expect continued rapid progress of this sort in the future.

In some sense, the idea of performance-enhancing aids to accomplishing mental tasks is relatively simple to understand. A \$4 handheld, solar battery powered calculator automates some arithmetic computation tasks, including calculating square root. If you are trying to accomplish a task that requires doing arithmetic on multidigit numbers, a calculator is apt to increase your productivity (speed and accuracy). If the task requires millions or billions of arithmetic calculations, a computer can increase your productivity by a factor of many millions.

In other situations, the idea of aids to mental tasks is subtler. For example, in writing this chapter I made use of some memorized information about Drucker, exporting jobs, Kurzweil, MIT, Negroponte, telecommuting, and so on. I then made use of the Google search engine, a Web browser, and the Web (a component of the Internet) to look up information on these topics. The ICT did a lot of mental work for me, and it facilitated a trial and error approach to discovering information that fit my needs. The ICT substantially increased my "library research" productivity.

The calculation example and the library research example provide some insight into how ICT is used to increase mental productivity. Clearly, each example has educational implications. The next two chapters of this book delve deeper into some aspects of possible futures of ICT in education.

Personal Growth Activities for Chapter 6

1. Think about the ranges of tasks that are involved in being a good teacher. Think about which (if any) of these lend themselves to increased productivity, and which do not seem to have this characteristic. Stretch your thinking about possible meanings of productivity. For example, has the entertainment industry become more productive in providing you with good entertainment and/or providing you with the wherewithal to better entertain yourself?

Activities for Chapter 6

1. Nicholas Negroponte is an educator and a futurist. Read some of his writings and develop a paper based on his forecasts for and recommendations on the future of education. As a starting point, you might want to look at his 1998 article in Wired Magazine given at (Accessed 5/22/05) <http://web.media.mit.edu/~nicholas/Wired/WIRED6-09.html>.

2. This chapter draws heavily on the work of Peter Drucker, a businessman. Peter Senge is another business leader who is quite interested in education. Read some of his writings and write a report on his insights into improving education. As a starting point you might want to look at (Accessed 5/22/05): <http://www.infed.org/thinkers/senge.htm>.
3. Analyze our educational system and teaching/learning processes from a bits and atoms point of view.

Chapter 7: Forecasts for ICT as Content in Non-ICT Disciplines

Try to learn something about everything and everything about something. (Thomas H. Huxley)

Through learning we become able to do something we never were able to do. (Peter Senge)

This chapter is built around three themes:

1. Tools embody knowledge and skills. A person who learns to make use of tools developed by others is gaining some of the knowledge and skill of the original developers of the tool.
2. Each of the disciplines that students study in school incorporates both general-purpose tools that cut across many disciplines and tools that are specific to the discipline. The former can be thought of as parts of a general Liberal Arts education, while the latter can be thought of as an integral part of the content of the discipline.
3. Over the centuries, science and technology have produced, and will continue to produce, tools that are powerful enough to produce paradigm shifts in disciplines and in the field of education.

The chapter explores these three themes from a point of view of ICT-based and ICT-related tools. The overarching forecast is these tools will get better at a substantial and increasing pace.

A Paradigm Shift

Here is a dictionary definition of the word paradigm:

par·a·digm n

1. a typical example of something
2. an example that serves as a pattern or model for something, especially one that forms the basis of a methodology or theory

A paradigm shift is a change in paradigm. For example, the shift from horses as a major mode of transportation to cars as a major mode of transportation was a large paradigm shift brought about by the development of automotive technology and infrastructure.

Earlier in this book, I mentioned Public Law 94-142 (1975) as federal legislation that led to a significant change in the special education component of our precollege educational system. This law and subsequent implementation of its provisions represents a major paradigm shift in the education for one particular group of students.

The disappearance of the card catalog from libraries, and their replacement by online electronic catalogs, represents a major paradigm shift in accessing information. This has been accepted in our schools, so most students currently in school are no longer learning how to use a card catalog.

The cell telephone represents a major paradigm shift from the hardwired telephone. Major paradigm shifts have occurred during human history in many areas. For example, moving from the hunter-gather era into the agricultural era was a major paradigm shift. Since then, we have had the major shift into the industrial era and then into the information age era. We have gone

from hot air balloons to propeller driven airplanes to jet engine airplanes. We have gone from terrible epidemics of polio and smallpox to routine use of vaccines for these and other diseases.

In education, we have gone from education of a few “elite” to education of the masses. We have gone from a grammar school education being adequate for most people to a high school education being considered minimal. Back in the early 1900s when my mother was growing up, the majority of women did not graduate from high school, and a college education for women was not at all common. Now, in the United States, more women than men are getting bachelor’s degrees.

Many of the types of changes (improvements) that have been implemented have an upper limit. For example, we can move from five-percent of children getting a grammar school education to close to 100% of children getting a high school education. However, we cannot achieve more than 100% of children graduating from high school. The idea of Upper Limit Theory is illustrated in Figure 7.1.

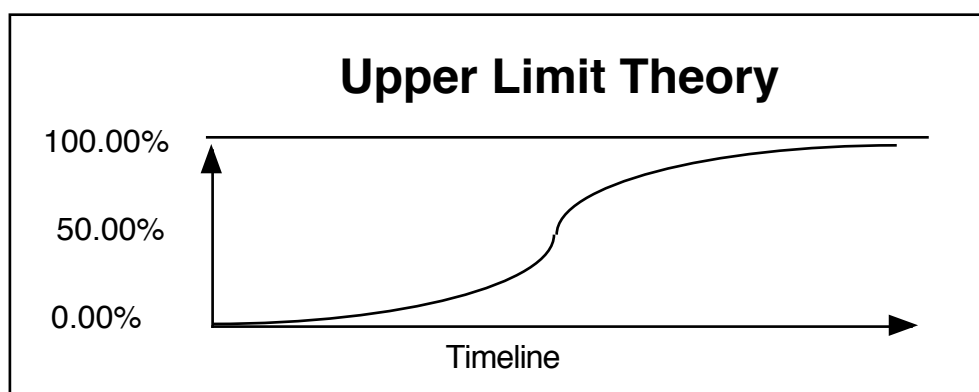


Figure 7.1. Illustration of Upper Limit Theory.

We want all children to get a good education. Our expectations for what constitutes a “good” education continue to grow. The totality of human knowledge continues to grow quite rapidly. As we think about these things and plan for the future of ICT in education, the idea of Upper Limit Theory becomes paramount.

Consider, for example, how long it takes for a student to gain a level of expertise that meets contemporary standards in a disciplines such as the three Rs, a science, or a social science. Now consider the fact that there are thousands of disciplines and sub disciplines in which a person might strive to achieve a useful (functional) level of expertise. In such endeavors, the student is faced by the fact that the totality of accumulated knowledge in each discipline and sub discipline is very large and growing rapidly. Thus, the amount of knowledge and skill needed to meet some sort of contemporary functional standards is steadily increasing. In addition, some of the new knowledge and skills tends to decrease the usefulness of older knowledge and skills.

One way to address this steadily growing problem is to develop tools that are easy to learn to use, easy to use, and that incorporate a significant amount of the knowledge and skills of a discipline.

Tools Embody Knowledge and Skills

The Information Age brought us factory automation. Machinery was developed that automated many tasks that used to be done by hand. In essence, an automated piece of

manufacturing equipment embodies some of the manufacturing knowledge and skills of the types of workers who previously did the job by hand.

If you are a Harry Potter fan, you have noticed Harry Potter writing with a quill pen. It takes a reasonable amount of training and practice to learn to select an appropriate quill, cut it appropriately, and hold it appropriately when writing. In the days of quill pens, most people also made their own ink.

Contrast this with the development of iron tip pens, fountain pens, and then ballpoint pens with a large built-in ink supply. You can see a trend toward decreased knowledge and skill needed on the part of the end user. In some sense, knowledge and skill about making a pen and its ink are now embodied in the ballpoint pen.

Or, think about a dictionary. Samuel Johnson, of London, published his *Dictionary of the English Language* in 1755. A dictionary contains information about the spelling and meanings of words. Clearly, a dictionary embodies a lot of knowledge. It is a valuable aid to reading and writing.

Now, consider a computer system that includes a modern word processor and a printer. The word processor includes a built-in dictionary and a number of other aids to writing. The printer takes the place of “by hand” writing or printing. The word processor may well contain a grammar checker that has embodied a substantial amount of knowledge about good grammar.

We can carry this example still further. With the ICT facilities, the writer can also design and publish his or her product. If publication is done via the Web, almost instantaneous worldwide availability occurs. If readers are willing to read electronic copy, then it is bits, rather than atoms, that are produced and distributed.

The sequence of examples, from quill pen to ballpoint pen to dictionary to word processor and printer, to electronic publication and distribution describe a trend. The underlying problem being addressed is that of providing aids to a person who is writing and then publishing his or her writing. The tools that have been developed can be thought of as aids to automating parts of the writing process. When appropriately used, such tools make some contribution to increasing the productivity of a writer, the quality of the resulting final product, and the distribution of this product. ICT has facilitated a major paradigm shift in writing and publishing.

Generic Tools

The term "generic tool" is used in this document to represent ICT tools useful in many different disciplines and that might be taught to most or all students at the PreK-12 level. Typical candidates for this designation include:

- Word processor.
- Database.
- Spreadsheet.
- Graphics (both Paint and Draw).
- Graphing (of data and functions), using both computers and graphing calculators.
- Desktop publication systems.
- Desktop presentation systems.
- Facilities to still pictures, video, and sound.

- Multimedia and interactive non-linear hypermedia systems, including working with digital still and motion video, color, sound, and animation.
- Telecommunications and connectivity, including email, the Web, search engines, and groupware.
- Calculators (the full range, from low-end 4-function calculators to high-end calculators that can solve equations, graph functions, and may be programmable).

Figures 7.1 and 7.2 represent expertise scales for a teacher and for a student that apply to a generic tool. The scale in Figure 7.1 makes use of the National Educational Technology Standards developed by the International Society for Technology in Education (ISTE NETS, n.d.).

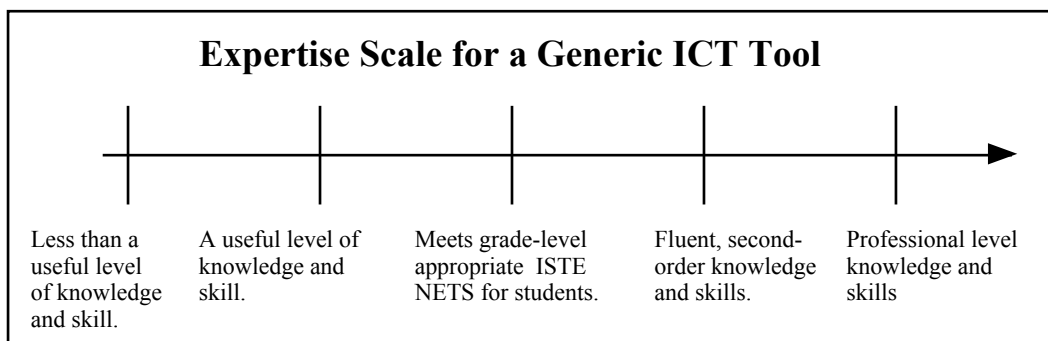


Figure 7.1. Generic ICT tool expertise scale for a student.

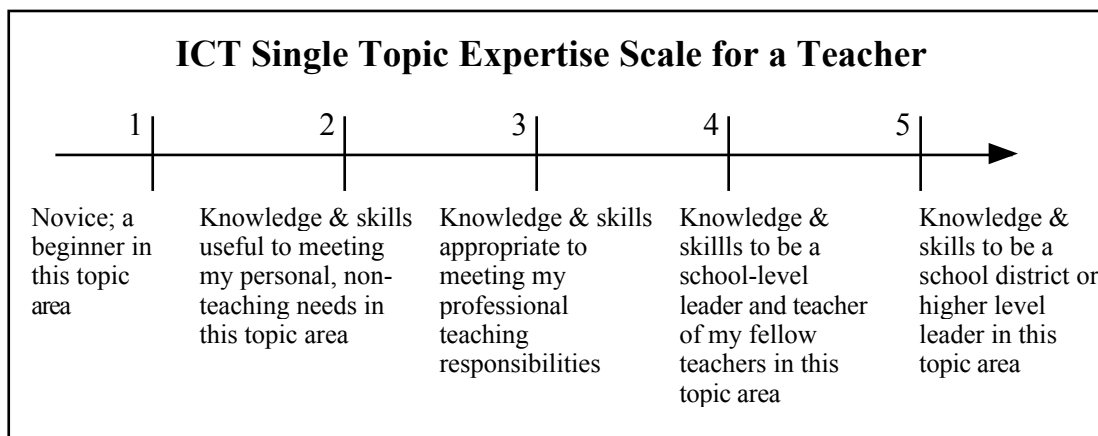


Figure 7.2. Generic ICT tool expertise scale for a teacher.

Taken together, Figures 7.1 and 7.2 point to an important part of the future of ICT in education. Many states have adopted the ISTE NETS, or some variation of these standards for students, teachers, and school administrators. Such standards provide guidelines useful both in developing programs of study and in accountability. Over the long run I predict that we will see:

1. Continued gradual progress toward students, teachers, and school administrators meeting and being held accountability for standards such as those provided by ISTE NETS.

2. That curriculum, instruction, and assessment will make gradual progress toward thoroughly integrating a wide range of generic ICT tools into the routine everyday, classroom activities of instruction and assessment.
3. That additional generic tools will emerge and that the standards of performance expected in use of generic tools will gradually increase. For example, I believe that Graphic Information Systems (GIS) will come into much more common use.

The acceptance of and implementation of the above ideas will constitute a major paradigm shift in education. In essence, it is something akin to adding a fourth “R” to the three Rs.

Retrieval of Information

How does a discipline store and retrieve its accumulated results? This section considers information retrieval from three points of view:

1. A generic-level of knowledge and skills using generic aids to the storage and retrieval of information.
2. Domain specific knowledge and skills using generic and/or domain-specific aids to the storage and retrieval of information.
3. Retrieval and use of information that is in a form to be used by automated physical and mental aids to solving problems and accomplishing tasks.

Information storage and retrieval became an important and challenging discipline long before computers came on the scene. A dictionary can be thought of as a generic tool, cutting across all areas of reading and writing. But, what about a medical dictionary or a mathematics dictionary? What about a French-English dictionary? What about a computerized language translation system that can accept French text as input and produce English text as output?

The retrieval and use of information is significantly changed through the use of computers. For example, consider the situation when a person uses a computer to retrieve business data, a spreadsheet program and graphing software to help analyze the data, and then uses a computer to send instructions to an automated machine to implement some of the ideas resulting from this information retrieval and analysis task.

The next three subsections expand on the above ideas.

1. Generic Information Retrieval Tools

The chances are that you have quite decent knowledge and skill in use of a browser and search engine to retrieve information from the Web. In some sense, you use the Web like an electronic encyclopedia. Of course, this encyclopedia is millions of times larger than a print encyclopedia.

From a typical user’s point of view, the problem lies in a Web search producing too many results. For example, on 5/23/05 I used Google to search on *future of computers in education*. The Google search engine reported that it found 23,900,000 Web pages. Wow! That is too much information! (Of course, I was pleased to see that one of my Websites was third on the list of hits! I was also pleased to see that when I changed the search phrase to *Moursund future of computers in education*, I got 5,640 hits.)

Clearly, I need to know how to more carefully specify my information needs. For example, suppose I am interested in the *future of computers in math education*. My Google found

10,800,000 Web pages. If my interest is the *future of computers in primary school math education*, Google found 2,360,000 Web pages. As I continued to try to narrow my search, I searched on the phrase *left handed student's future of computers in primary school math education* and still ended up with 57,900 hits. Finally, I used the search phrase "*left handed*" "*red headed*" *girl's future of computers in primary school math education* and obtained 15 hits.

The point to this silly activity is that I am not communicating effectively with the search engine. What do I really want to know, and how do I specify my request in a form that the search engine can help me? I need to learn the capabilities and limitations of search engines. I need to learn to communicate more effectively with search engines.

Now, back to forecasting the future. I have an information retrieval and an information overload problem. Lots of people have similar problems. There are two obvious approaches to dealing with this problem:

1. Change our school curriculum so that it includes a significant amount of instruction in making effective use of the Web and search engines. (Research librarians know a lot about this information retrieval discipline.)
2. Make the Web and search engines "smarter."

I can predict with considerable confidence that the second of these two approaches will occur, as there are already substantial efforts underway to accomplish this task. It is not at all obvious that our school systems will do much about the first approach. Essentially all students are learning to search the Web. But, few are developing the knowledge and skills to do effective searches in the various disciplines that they are studying.

It is now common for students in our K-12 educational system to learn to use a variety of generic computer tools. However, for the most part, the level of learning is superficial. Our educational system "talks the talk" about increasing the focus on higher-order thinking and problem solving. However, it is not doing well in "walking the walk." My forecast for the future is that our educational system will make very slow progress in this area (Moursund, 2002b).

2. Domain Specific ICT Tools

Each discipline develops its own special vocabulary, tools, and methodologies. This means that a person who is learning a specific discipline needs to learn how to retrieve and use information specifically within that discipline.

To be more specific, consider the situation where a person is faced by a problem to be solved or a task to be accomplished within a specific discipline, or a narrow domain within a specific discipline. Perhaps the most important idea in problem solving is building on the previous work of others and oneself. This means drawing upon one's own knowledge and the collected knowledge within a discipline. This collected knowledge is distributed worldwide and much of it may not be readily available. Learning a discipline includes learning how to cope with such difficulties.

As an example, I have a doctorate in mathematics. Both my undergraduate school (the University of Oregon) and my graduate school (University of Wisconsin, Madison) had math libraries. Part of my undergraduate and graduate education was learning how to "look up stuff" in the math library. The reality was that I learned essentially nothing about this as an undergraduate, or even during my first two years of graduate school. In retrospect, it is clear that this was a major flaw in my mathematical education.

The Web can be considered as a Global Library. It is continuing to grow quite rapidly, and its non-English language content is growing more rapidly than its English-language content. Computerized language translation for a number of languages is now available, but such translations are of modest quality.

When I think about the information given in this subsection, I come to the conclusion that each teacher has a responsibility for helping his or her students gain domain-specific information retrieval skills within the domains that the teacher teaches. This has some importance at the precollege level, and much more importance in higher education. As a precollege example, where can a student find information that from a course the student took the previous term or in a past year? If a course is based primarily on one textbook, where can the student find other points of view and other approaches to presenting the information? If a student has a particular learning style in a particular course, where can the student find instructional materials that play upon this particular learning style?

3. Information Retrieval and Automation

There is a good chance that you have watched a Star Trek television episode or movie. One of the pieces of technology in this science fiction story is called a replicator. In essence, a replicator turns bits into atoms and molecules. Thus, crewmembers on the various starships replicate food that they then eat.

Of course, we are a long ways from having this technology. But, we do have fully automated manufacturing tools that can “replicate” a variety of products by following instructions stored in a computer. As a simple example, consider a books and music store that carries no books and music inventory. A customer specifies to a computer system a book and some pieces of music that he or she wants to purchase. The store’s ICT system retrieves the needed bits (perhaps from a computer located thousands of miles away) and then prints and binds the book, and burns the music onto a CD or DVD. While the cost and time of printing and binding just one copy of a book or burning just one copy of a CD does not match that of a mass production line, the overall costs of this approach to manufacturing and distributing is cost effective for books and pieces of music that have only limited sales.

An alternative to producing hard copy is to just have the computer system download the book or music to a personal storage device. That is now common. For such an activity, one does not need to go to a nearby physical store. The whole transaction can be done over the Internet.

More sophisticated examples are found by looking at computer-driven lathes that can automatically produce a product out of wood, metal, plastic, or some other stock. The computerized lathe probably runs faster and more accurately than a by-hand lathe. And, the lathe can make very quickly changes to producing a different product. In essence, the knowledge and skill needed to make a part are embodied in a computer program that directs the lathe to make the part.

Still more sophisticated examples can now be found in the processes used to “print” a component. In essence, a printer-like device builds up a product layer after layer, using a ceramic or plastic material to print with. For example, it is now possible to “print” plastic lenses for eyeglasses.

Now, you may ask, what do these examples have to do with education? Many people assert that the main goal of education is to prepare students for the jobs they will have in the future. It

is very difficult to accurately forecast the nature of these jobs. Thus, job-specific education is a poor approach. Chapter 6 began with the quote that suggests a much better approach:

The illiterate of the 21st century will not be the one who can not read and write, but the one who can not learn, unlearn, and relearn. (Alvin Toffler)

Additional Ideas About Domain-Specific ICT Tools and Content

Chapter 3 emphasizes the idea of expertise in a discipline as it states that a discipline can be defined by a combination of:

- The types of problems, tasks, and activities it addresses.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, language (including notation and special vocabulary), and methods of teaching, learning, and assessment.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- The knowledge and skills that separate a novice from a “reasonably competent” from an expert from a world-class expert. Each discipline has its own ideas as to what constitutes a high level of expertise within the discipline and its sub disciplines.

Figure 7.3 is nearly the same as Figure 2.1, the only difference being the insertion of ICT at the start of the upper left and upper right statements. The center of the diagram is a problem-solving, task-accomplishing team. The bottom part of the diagram stresses the idea of having an educational system that prepares team members to work together with each other and with the various ICT aids that are relevant to the problem or task.

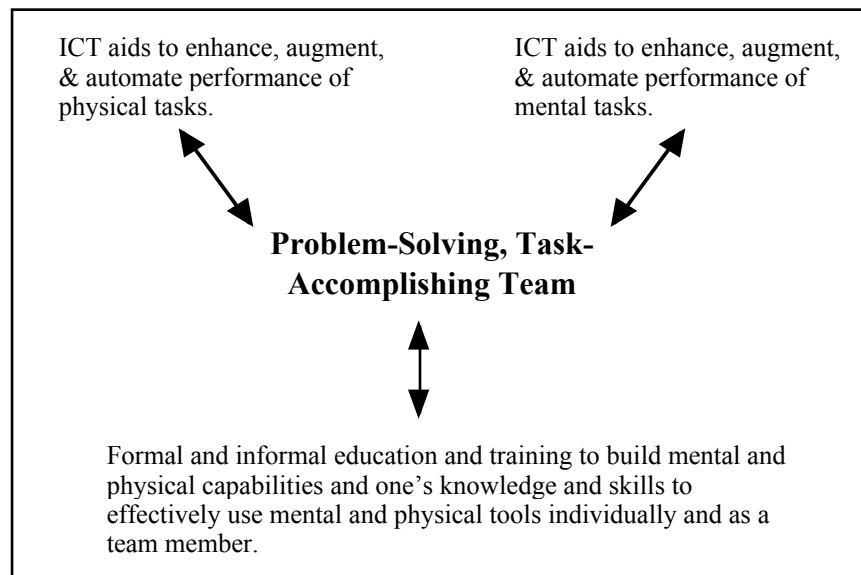


Figure 7.3. ICT and performance of physical and mental tasks.

Suppose we think about a student moving up an expertise scale for each discipline that he or she studies at the precollege level. There are many different aspects of having expertise in a

discipline. Part of what increasing expertise means is getting better at solving the problems and accomplishing the tasks in the discipline. Solving problems and accomplishing tasks in a discipline requires some combination of physical and mental activity. The requirements vary considerably both within a discipline and from discipline to discipline. However, ICT is now a significant domain-specific component of the content of most disciplines in the precollege curriculum.

Fine Arts, Graphic Arts, and Animation

As an example, let's look at the field that includes fine arts, graphic arts, and animation. This field can be thought of as a whole, or you might want to think of it as consisting of three separate disciplines:

- fine arts: the study and creation of visual works of art.
- graphic arts: the crafts, industries, and professions related to designing and printing on paper, display screens, and other substrates. Includes engineering and architectural drawing.
- animation: creating a sequence or series of graphic images or frames to give the appearance of continuous movement.

From a historical perspective, photography and then motion pictures brought new media into the world of art. You can think of this as new tools that expanded the field of art. Color photography and color motion pictures further expanded the field of art.

Now, think about how ICT has contributed to art. If your focus is on the fine arts, you can think of ICT as providing a new medium. A person can paint and draw using an ICT system and produce results to display on a computer display screen. A computer system provides an artist with a variety of tools. Some are like by-hand tools, such as a brush or a drawing tool. Other tools are somewhat or a lot different. For example, the erase tools are quite a bit different than the by hand tools to "erase" when painting with oils or watercolors. Cut, or copy and paste, when working in a computer fine arts environment are quite a bit different than when working in an oil or water color environment.

The graphic arts industry has been substantially changed by ICT. A simple example of this is provided by desktop publication. A word processor contains tools (and "knowledge") that allow a person to do many of the tasks that formerly were done by professionals in page design and page layout. A somewhat more complex example is provided by the changes we have seen as mechanical drawing has been replaced by computer-assisted drawing,

In recent years, ICT has substantially changed animation. Nowadays, many of the movies that are being created make significant use of computer animation. The state of the art of such computer animation now allows the creation of animals, people, ocean waves, and so on that are of sufficient high quality that the viewer cannot tell them from the "real" thing.

The uses of ICT mentioned above are quite empowering to the artist. We all know revision is one of the key aspects of producing high quality writing. Computers make it much easier to revise photographs, movies, drawings, page layouts, animations, and so on.

All of the above has had some impact on precollege education, and there is great potential for additional integration into the curriculum. As an example, Kid Pix software is designed for use by quite young students. It provides an environment in which children can draw, paint, animate, and edit (Kid Pix, n.d.). Logo provides an even richer learning and creative expression

environment (LCSI, n.d.). At the secondary school level, the mechanical drawing courses have been replaced by a Computer-Assisted Design/Computer-Assisted Manufacturing courses (CAD/CAM).

Music

In this section we will briefly discuss ICT and the field of music. Some people define “music” broadly enough so that it includes any sound. If you are interested in the sounds in our environment, then you are interested in Acoustic Ecology (WFAE, n.d.). As you view and think about a movie, you will notice that the music is in some sense one of the characters in the movie, and that other aspects of the soundtrack are fundamental to creating the atmosphere and communication provided by the motion picture.

There are a number of major components of the field of music. The Musical Instrument Digital Interface (MIDI) is an important aspect of ICT in music.

Musical Instrument Digital Interface: enables a computer to control devices, such as synthesizers and sound cards, that emit music. Computers with a MIDI interface can record sounds created by a synthesizer and then manipulate the data to create new sounds. A variety of programs are available for composing and editing music conforming to the MIDI standard. (www.oit.ohio-state.edu/glossary/gloss2.html)

MIDI is the professional standard interface for hardware being used to digitally compose, edit, and perform music. Electronic music existed for a long time before the MIDI standards was developed in the early 1980s (MIDI History, n.d.).

As microcomputers began to build-in sound systems and output to speakers, many different pieces of software have come to include facilities for composing, editing, and performing music. This has made it possible to use an “ordinary” microcomputer to create an environment in which young students can learn to compose and edit music, and then have the music performed by the microcomputer (Kid Pix, n.d.; LCSI, n.d.). This is a quite inexpensive way to add a new dimension to music instruction in an elementary school, as it makes use of the computer hardware that is already available in the school.

A number of secondary schools now have a “MIDI lab.” That is, they have a music lab that contains a number of MIDI keyboards, microcomputers, and good sound systems. Students can take courses in composing, editing, and performing music in this environment.

Computational Component of a Discipline

In January of 2004, I did a Google search on the term *computational*. (My May 2005 search on the same term in Google produced over 41,000,000 hits.) The first 50 of the 4,500,000 “hits” include topics such as computational beauty of nature, computational biology, computational chemistry, computational economics, computational epistemology, computational fluid dynamics, computational geometry, computational learning theory, computational linguistics, computational mechanics, computational molecular biology, computational paleontology, computational physics, computational science, computational science and engineering, and computational statistics.

All of the Web pages that I explored have to do with computer modeling and computer simulation as an aid to representing and solving the problems within various disciplines. The large number of hits from these various searches suggests that the content of a large number of different disciplines has already been affected by ICT.

Modeling and simulation are not new tools or methodologies. However, ICT has contributed substantially to the tools and methodologies. Quoting from Simulation (n.d.):

Established in 1952, The Society for Modeling & Simulation International (SCS) is a nonprofit, volunteer-driven corporation (dba Simulation Councils, Inc.). SCS is the only technical Society dedicated to advancing the use of modeling & simulation to solve real-world problems. SCS is the principal technical society devoted to the advancement of simulation and allied computer arts in all fields. The purpose of SCS is to facilitate communication among professionals in the field of simulation.

To help you understand modeling and simulation, let me give a simple example from physics. The formula $d = .5 gt^2$ is a mathematical model for the distance (d) that an object falls in time (t) under a uniform pull of gravity (g) when there is no air resistance. Using this formula one can develop a simulation for a projectile motion (such as a cannon shell fired from a cannon located on the earth's surface). The simulation can be used to predict where the cannon shell will hit when the cannon is fired at a particular angle and muzzle velocity. Such a simulation (prediction) can be made more accurate by taking into consideration air resistance, wind speed, and wind direction. In summary, one develops a mathematical model, and then one makes predictions based on computer simulations using the model.

The 1979 spreadsheet software for the Apple IIe microcomputer was immensely successful. Tens of thousands of people bought Apple IIe microcomputers so that they could use this software as an aid to representing and solving certain types of business problems. In essence, with a spreadsheet a person can develop a mathematical model of a payroll, income and expenses, or other aspects of a business. This spreadsheet model can then be run with different inputs, such as a change in wages, an increase in production, and so on. These simulations (posing and answering "what if" questions) are a valuable forecasting and planning tool.

You know that a photograph is not the object being photographed, and "a map is not the territory." However, a photograph may contain or represent a lot of information about the object, and a map can be very useful in planning a trip across the mapped territory.

A computer model of some aspect of a business is not the business. If the model, and then the simulation based on the model, accurately represents certain aspects of the entity being modeled and simulated, then accurate forecasts can be made.

This overall modeling/simulation situation can be highly complex. For example, consider long-range weather forecasts based on computer models and simulations of the weather. To make an accurate forecast, you need accurate data of the initial situation (the weather at the start of the simulation). You also need a good model (for example, you need to thoroughly understand the physics and fluid dynamics involved). Finally, you need very fast and accurate computers, because the models involve a very large number of variables and the equations to be solved are very complex.

Our precollege curriculum largely ignores the topic of computer modeling and simulation. This is at a time that these tools have become standard aids to representing and solving the problems in a number of different disciplines, including all of the sciences. This situation suggests the forecast that eventually our precollege curriculum will appropriately reflect computer modeling and simulation. At the current rate of progress, however, "sometime" seems to me to be a very long time in the future.

Problem Solving, Task Accomplishing, Question Answering

Some of the forecasts given so far in this book point to the increasing value of an education slanted toward problem solving, task accomplishing, and posing and answering questions. These are all aspects of higher-order thinking and cognitive processing.

ICT provides a wide range of aids to solving problems, accomplishing tasks, and answering questions. Research in problem solving, task accomplishing, and question answering indicates the domain specificity (that is, high dependence on the specific domain of the topic under consideration) of such activities. Thus, it behooves each teacher of a discipline to help his or her students to learn to pose and solve problem, pose and accomplish tasks, and pose and answer questions that are specific to the discipline he or she is teaching.

As you might expect, my forecast in this area is that our educational system and teachers will make significant improvements in this area over the next couple of decades. Evidence of progress in this endeavor can include:

- “Open computer with Web connectivity” tests. Think of assessment moving from: A) closed book; B) to closed book with a page of notes; C) to open book and open notes; D) to open computer; E) to open computer with connectivity.
- Problem posing, task posing, and question asking being a routine part of the curriculum in each discipline students are studying.
- Students, individually and collectively, routinely spend time working to solve the problems, accomplish the tasks, and answer the questions that they pose.
- Increasing amount of curriculum time being spent on higher-order thinking and other cognitive activities.

Microcomputer-Based Laboratory

For many years, computer technology has been used in the design and construction of wide range of increasingly automated and “smart” science tools. As a simple example, consider methods for measuring acidity. For a wide range of applications, the pH meter has replaced acid/base titration and the use of litmus paper (Estuarine Science, n.d.). The scanning electron microscope provides a more sophisticated example. Your students may enjoy exploring an educational Website on scanning electron microscopes (SEM, n.d.).

A still more sophisticated example is provided by the totality of equipment used to send a rocket ship to Mars, land a Mars rover, gather data from the surface of Mars, and send the data back to Earth. Such equipment is getting so good that it has led to heated arguments about the value of sending people to Mars versus the value of unmanned flights.

Both at the precollege level and the college level, microcomputer-based laboratory (MBL) is having a significant impact on the teaching and learning of science. The essence of such MBL is providing students with relatively inexpensive ICT-based tools to help them do exploratory, hands-on science investigations. Quoting from MBL(n.d.):

The microcomputer-based laboratory (MBL) is a tool for collecting, analyzing, and displaying data from science experiments. It is commonly used in instructional laboratories, and less used in interactive demonstrations. Commercial MBL probes have been commonplace since 1985, but there have been relatively few research studies on the effects of student and teacher use of this tool on learning and experimenting.

As an aid to teaching and learning, MBL adds considerable authenticity even though the versions of the tools used in teaching tend to be less sophisticated and much less expensive than those used in science labs and other non-education applications. TERC has been a long time leader in developing educational resources to support MBL (Kimball, 1995). There has been substantial research that supports claims of improved student learning and understanding in MBL science education environments. The combination of increased authenticity, increased student involvement, and increased learning all suggest that MBL will continue to grow in importance in our schools of the future.

Lower-Order and Higher-Order Uses of ICT

Word processor, email, and the Web are three ICT tools that have been widely adopted in education. These tools share three characteristics:

1. They help a user to better accomplish tasks that the user already knows how to accomplish and benefits by accomplishing. For most people, the advantages of these tools are rather obvious.
2. They are easy entry ICT tools. With relatively little formal or informal training/education in use of the tools, a typical person gains knowledge and skills that are quite useful.
3. With increasing amounts of training, education, and experience, a person can gain a substantially increased level of expertise in using the tool.

The third point is quite important. People sometimes talk about easy entry, no ceiling. A somewhat different way of looking at this is shown in Figure 3.4.

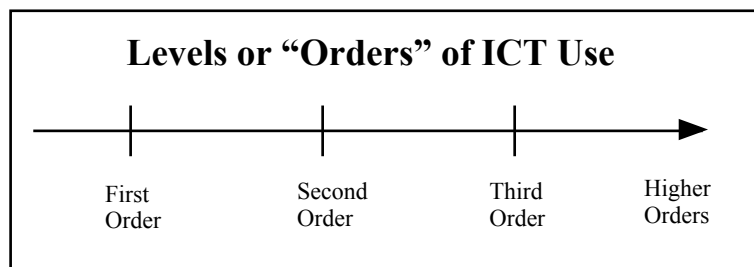


Figure 7.4. Levels of “orders” of ICT tool use.

The terms first order, second order, etc. are not very well defined. Moreover, we are not carefully distinguishing between a tool and various levels of skill in using the tool. However, here is a brief discussion that will help you to better see into the future of ICT tools.

1. First order use of a tool is at an amplification level (Moursund, 1997). The horseless carriage (early car) was an amplification of the horse and buggy. A word processor can be used so that it is just a simple amplification of an electric typewriter.
2. Second order moves the user well beyond amplification, but the user still provides most of the needed brainpower. Think of an electric typewriter versus the first word processors versus today’s range of aids to writing and desktop publication that are included in a modern word processing system. Think of the capabilities of a well-trained research librarian making use of the web (our Global Library). More examples of second order are given in Moursund (2002b).

3. Third order represents moving beyond second order in terms of significantly increased intelligence and automaticity built into the ICT system and effectively used by the user. Think of the autopilot in a jet airliner, or the various aspects of current Mars rover projects. Or, consider an architect doing a detailed first draft of a new office building, making full use of computer graphic tools. At a third order level the ICT system would automatically be checking for energy efficiency calculations and suggestions, structural integrity (including resistance to wind, earthquakes, and large airplanes), meeting electrical and fire codes, and so on. At the third order level, the ICT system incorporates a large amount of the accumulated knowledge of the task to be performed and problem to be solved. The ICT system uses this knowledge in an appropriate and useful interactive manner with the human who is using the ICT system.
4. Still higher orders are based on ICT systems that have a high level of understanding of the task to be accomplished or the problem to be solved. Movement toward higher order is exemplified by the ICT system being to automatically accomplish complex tasks and solve complex problems without human intervention. A human (or, perhaps an ICT system) describes the task or problem in rather broad terms. The ICT system and the human interact to clarify the task or problem. Then the ICT system takes over.

To summarize, ICT tools enhance a person's abilities to accomplish certain tasks and solve certain problems. The scale of Figure 7.4 suggests high and higher levels of enhancement, with more and more of the needed brain power and physical power being provided by ICT and physical tools that make use of ICT. At the current time, much of the use of ICT in education is at the First Order level. Business, industry, military, and many non-education users are pushing the envelop, creating Second Order and Third Order ICT tools, and learning to make effective use of them. In the future we can expect that our educational system will slowly move up the scale.

Concluding Remarks

ICT is a powerful aid to representing and solving the problems (tasks, questions) in each academic discipline. ICT has greatly enhanced the power of (the value of) modeling and simulation in each discipline. ICT has added new dimensions to many fields. In brief summary, ICT has already provided us with many generic tools and methodologies that cut across most disciplines, and with many domain-specific tools and methodologies.

The potential of ICT to make a significant contribution to our educational system lies mainly in the nature and extent to which we incorporate the power of ICT in two major paradigm shifts:

- Helping students learn to understand and make effective use of ICT as an aid to solving challenging problems, accomplishing challenging tasks, and answering challenging questions in each discipline they study.
- Helping students learn the various disciplines they study. (The next chapter focuses on this topic.)

Personal Growth Activities for Chapter 7

1. Reflect on some of the big ideas of this chapter. (Think in terms of possible paradigm shifts in education.) Pick one of these and reflect on the nature and extent to which you integrate this into your teaching or are prepared to integrate this into your teaching. The pick a second big idea and do the same thing. What are your feelings and conclusions from these reflections?

Activities for Chapter 7

1. Have you ever used a spreadsheet to develop a computer model and then to run simulations based on the model? If “yes,” briefly describe some of your experience in this area. If “no,” give one or more examples of where this could have been part of your education if your teacher had had appropriate knowledge and students had had appropriate access to computers.
2. Select a specific discipline that you teach or are preparing to teach. Pretend you are a student at the grade level that you teach or are preparing to teach. Pose some challenging problems, tasks, and questions that you (as a pretend student) think are appropriate to the discipline and grade level. (Note that such “pretending” is, in some sense, doing a simulation.)
3. The next time you teach a class, have the students pose some questions that they expect to learn how to answer as a result of studying what you are teaching. Working with the students, explore the idea of lower-order and higher-order knowledge and skills. Working with the students, analyze the questions from the point of view of lower-order versus higher-order. Working with the students, spend some time exploring possible roles of ICT as an aid to the students answering the questions on their own.

Chapter 8: Forecasts for Computer-Assisted Learning and Distance Learning

In traditional classroom-based education, teachers and students gather together in a classroom. The intent and hope is that in the classroom the teachers will teach and the students will learn. For the 5,000 years during which humans have had formal schools, this traditional classroom-based educational model has prevailed. The effectiveness of this approach has improved markedly over the years, as has the number of people receiving a substantial amount of formal schooling.

The field of Information and Communication Technology has made possible a variety of new modes of teaching and learning environments:

- Synchronous distance learning, such as a live, two-way video connecting a teacher with students in one or more classrooms.
- Asynchronous distance learning via a networked computer (where the network might be the Internet).
- Computer-assisted learning, an environment in which a student interacts with a computer system that has been designed to present instruction and facilitate learning.

In recent years the Science of Teaching and Learning (SoTL) has made significant progress. Some of the most exciting results in this field are coming from Brain Science. ICT has contributed greatly to research in SoTL as well as in the classroom implementation of this research. We now have some highly interactive intelligent computer-assisted learning systems that are more effective than traditional classroom instruction. The number of such systems will grow steadily in the future, and they will tend to merge in with asynchronous distance learning.

More about Upper Limit Theory

Chapter 7 briefly discussed the idea that there are many different natural occurring upper limits. Figure 8.1 is the same as Figure 7.1.

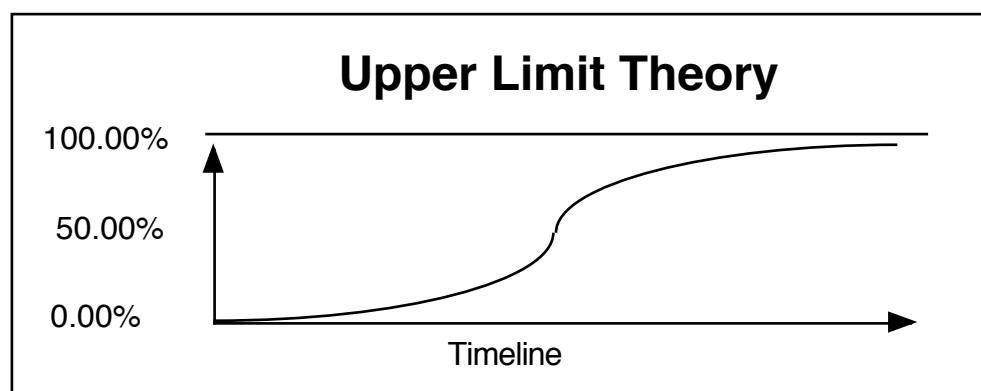


Figure 8.1. Illustration of Upper Limit Theory

Since the mid 1980s, Robert Branson has written extensively about Upper Limit Theory as it applies to our current K-12 educational system (Leigh, n.d.) Branson argues that by the mid 1960s, our precollege educational system had reached the 95% level. In his many articles he

presents substantial evidence that using the current teacher-centered paradigm of precollege education, we are doing about as well as we can do (Branson, n.d.). See Figures 8.2 and 8.3 for teacher-centered versus learner-centered paradigms. Branson argues that to significantly change education, we need a paradigm shift to a learner-centered model. Such a paradigm shift might build heavily on computer-assisted learning and distance learning, as discussed in the next sections of this chapter.

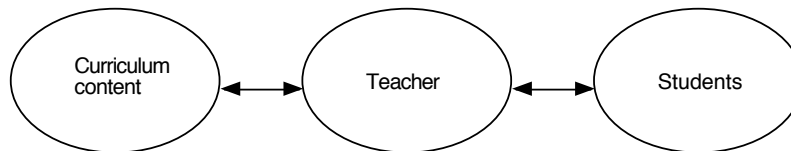


Figure 8.2. Teacher-centered educational paradigm.

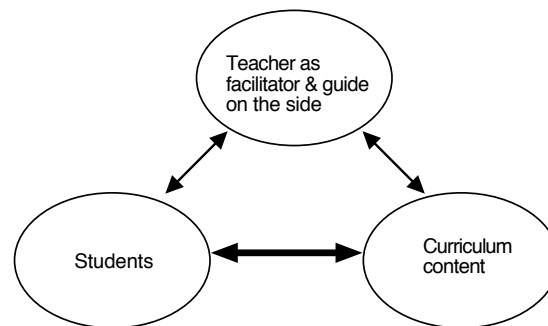


Figure 8.3. Learner-centered educational paradigm.

Computer-Assisted Learning

Computer-Assisted Learning (CAL) has had lots of different names over the past half century. Examples of other names include computer-assisted instruction and computer-based instruction. In simple terms, the idea is that a computer system can be developed that plays some of the roles of a teacher in a teaching and learning environment.

Initially, people tended to think in terms of using a computer system for drill and practice—an automated flashcard system. Such a system can keep track of the number of right and wrong answers and can be designed to automatically cycle back to the wrong answer situations. From a productivity point of view, such an automated flashcard system eliminates the need to a person to present the flashcards, record the results, and appropriately cycle back to re-presenting the cards where the student had given an incorrect answer. In this aspect of teaching, a computer can completely replace a human teacher.

Moreover, it is easy to further improve a computerized flashcard system. The system can be designed so that it analyzes a student's incorrect responses and provides instruction (a brief tutorial, for example) that may correct a student's misunderstanding. The system can be designed so that it adjusts to the level of a student's knowledge and skills. Thus, it automatically presents more challenging problems and questions.

Nowadays, the field of CAL has grown to include drill and practice, tutorial, simulations, and a variety of forms of virtual realities. For many years, people have worked to incorporate ideas

from Artificial Intelligence (AI) into CAL. The goal is to make the computer system “smarter” in its interaction with the student. For example, it would be helpful if a CAL system could accept and appropriately process written and verbal responses from a student. It would be helpful if the computer system could build a good understanding of what the student knows, what the student does not know, and how to move the student efficiently and effectively toward greater knowledge and understanding.

The previous paragraph describes the frontiers of a very important component of ICT in education. In essence, the goal is to use ICT to build a very high quality intelligence tutoring system. This goal will not be achieved quickly, through one dramatic breakthrough. Rather, progress toward this goal will be a gradual thing, extending many decades into the future.

However, significant progress has already occurred in some areas. We now have some highly interactive intelligent computer-assisted learning (systems that are more effective than one-on-one human tutors in quite domain-specific areas (HIICAL, n.d.). As an example, a small percentage of children are severely speech delayed because the phoneme processors in their brains function too slowly. The Fast ForWord software is an example of HIICAL that is more effective than human speech therapists in addressing this problem (Fast ForWord, n.d.).

The airlines, military, and pilot training schools make extensive use of flight simulators. These have evolved to the point of being HIICAL virtual reality systems. In such a training environment a pilot trainee (or, an experienced pilot receiving refresher training) can experience piloting situations that are both quite dangerous and that don't occur very often in the real world of being a pilot. That is, the flight simulator has some characteristics that make it better than a one-on-one human tutor.

As a summary to this section, the future will see more and more domain-specific HIICAL systems that are more effective (students learn better and faster) than one-on-one human tutoring. And, keep in mind that one-on-one human tutoring is far more effective than one teacher per 20 to 30 or more students that we have in conventional classrooms.

If you are interested in a “way out” forecast, then think of a child growing up with an intelligent robot companion that has a huge range of HIICAL knowledge and skills. Such a robot would assume some (quite a bit) of the childcare responsibilities that are now carried out by schoolteachers. This forecast may not seem so “way out” (perhaps less than 50 years in the future) after you read the following quotations. The first is from Rodney Brooks, director of MIT's Computer Science and Artificial Intelligence Laboratory. The second is from Hans Moravec, a research professor in the Robotics Institute at Carnegie Mellon.

I am convinced robots today are where computers were in 1978. That's about the year that computers started to appear around us in the way that robots are cropping up today. Of course, it was another 15 years before computers truly became pervasive in our lives. I think that 15 years from now, robots will be everywhere, as e-mail and the Web are now (Brooks, 2004).

Perhaps by 2020 the process will have produced the first broadly competent ‘universal robots,’ the size of people but with lizardlike 10,000 MIPS minds that can be programmed for almost any simple chore (Moravec, 2003, page 96).

The Moravec quote talks about MIPS, or millions of instructions per second. Current microcomputers have a speed of a few thousand MIPS. Thus, the microcomputer speed that Moravec is talking about will be reached in just a few years. Very roughly speaking, there appears to be about a 10-year lag between the speed of the current medium-priced microcomputers and the microcomputers being used in mobile robots. His 2020 estimate allows for this 10-year lag.

Moravec's article also contains estimates of the brain power of a mouse being 200,000 MIPS, that of a monkey being 1,000,000 MIPS, and that of a human being about 1,000,000,000 MIPS. Most people find it difficult to comprehend the meaning of such numbers. Roughly speaking, my current desktop computer has a speed of about 5,000 MIPS, which is 1/200,000 of the estimated brainpower of a human. Keep in mind, however, that supercomputers are being built by connecting thousands of fast microcomputers, and some problems are now being attacked making use of a million or more microcomputers connected via the Internet.

Distance Learning

At the current time, it is common to talk about Distance Learning and Traditional Classroom-based Education as being two distinct types of teaching/learning environments. For simplicity, we will refer to these as DL and TCE. DL is often broken into two categories—synchronous and asynchronous. A widely used model of synchronous DL is a two-way audio, two-way video connection between a teacher and one or more classrooms of students. A widely used model of asynchronous DL is a Web-based or email-based course with students progressing through lessons at their own pace.

Synchronous DL

Synchronous DL can be viewed as a way to avoid the educational problem of the teacher and the students needing to be gathered together in one location. With appropriate two-way connectivity, a teacher and students in a variety of locations can interact. Such synchronous DL has a distinct advantage in increasing the productivity of a teacher in certain situations. For example, consider the problem that small high schools have as they attempt to provide their students with a full range of Advance Placement courses. This problem can be solved by enrolling the students in courses that draw upon students located throughout the state, or perhaps throughout the country.

Synchronous DL can be done via two-way audio, but nowadays when people talk about synchronous DL they typically mean that two-way video is being used. Synchronous DL can also be done via broadcast TV and one-way or two-way audio. The defining characteristic of synchronous DL is that students and the teacher are locked into a set timeframe, all simultaneously involved in the teaching and learning process. Just as in a typical in school-based course, the course has a time schedule, with "meetings" on a regular schedule over a predetermined number of days, weeks, or months.

The environment of synchronous two-way video mediated interaction is not the same as the interactive environment that exists for a group of students and a teacher all placed together in a classroom. However, the situation is far better than the students not having access to the courses they want to take. Moreover, there has been a lot of research on synchronous DL. Roughly speaking, the research suggests that in terms of student learning, there is no significant difference as compared with Traditional Classroom-based Education (Russell, n.d.).

At the current time, synchronous two-way DL is most often carried out over a special network that is not part of the Web, and the connectivity used tends to be rather expensive. Some states have leased extensive networks for synchronous DL and/or installed their own connectivity. However, Internet2 has the bandwidth to support high quality interactive video. It seems obvious to me that Internet2 will gradually replace Internet1, and that as this occurs most synchronous DL will migrate to Internet2.

Asynchronous DL

The defining characteristic of asynchronous DL is that the students and the teacher are not locked into a fixed timeframe of simultaneous teaching and learning activity. There is no fixed time schedule of class meetings. Some asynchronous courses are tied to the term, or semester schedule of a school, starting at the beginning of a term and ending at the end of a term. Others are not constrained in this manner, and perhaps allow students to enroll and begin a course at any time, and complete the course under a time constrain that might be a year or more in length.

In a typical asynchronous DL course, the instructional materials and course syllabus are prepared by a team (the team may consist of one person), and the team may or may not contain the teacher or the teacher of record of the course. Historically, asynchronous DL made use of surface mail and airmail for interaction between an instructor and students. The instructional materials were print materials, typically books, a detailed syllabus, and other print materials. The DL course was called a Correspondence Course.

Rapidly changing technology over the past half century has greatly changed the correspondence course. The print materials have been supplemented by audio and videotapes. The delivery system has changed from using the postal service to using the Internet. It is now common to use the Web as an information delivery vehicle, and to use email for interaction between an instructor and students. Assignments are commonly submitted electronically.

The Internet facilitates interaction among students in both synchronous and asynchronous DL. Many synchronous DL courses include an asynchronous component of interaction among students and interaction with the course instructor or instructional assistants via the Internet.

The diagram of Figure 8.4 is useful in discussing the cost of preparing an asynchronous DL course. In this diagram, a “course” is a school year in length. The costs are very crude estimates. Notice that the increment on the cost scale is a factor of 20.

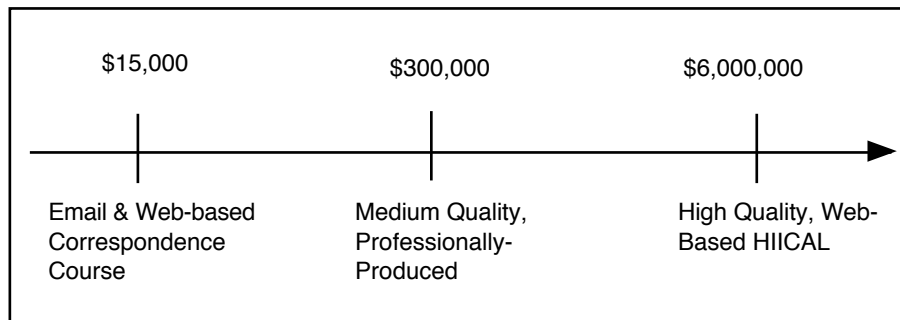


Figure 8.4. Costs of an asynchronous DL course.

The left end of the scale is intended to suggest that it is possible to create a Web-based “correspondence course-type” of DL at a cost of perhaps \$10,000 to \$20,000. The course materials make few provisions for interaction between the student and the Web-based courseware. Many thousands of such courses have been created by individual course instructors. Nowadays, this is often done with the support of a school district, a so-called Cyber School, or a company providing some technical support and overall guidance to the course instructor who is developing the course. Courses offered in this mode tend to depend heavily on a human instructor or “grader” to provide feedback and to do assessment. The computer-provided assessment tends to consist of T/F, multiple choice, and similar types of questions.

The middle range in the diagram describes DL courses developed by a team that may include a curriculum designer, a content specialist, a Web specialist, and other support personnel. The Web-based instructional materials may include substantial provisions for interaction between the materials and the student. The course may contain a substantial amount of Web-based materials that were created specifically for the course.

The right end of the scale portrays HIICAL that has been designed for Web delivery. It has a number of characteristics of a computer-based one-on-one tutor. Such courses tend to be near the “state of the art” of current DL. During their development, the materials are extensively field-tested. The course design and content is based on current research on curriculum content, instructional design, and assessment.

Even after a course has been created and adequately field-tested, it still needs regular maintenance and periodic update. A rough rule of thumb is that the yearly cost of such activity should be about 20% of the original development cost.

A HIICAL course, whether delivered via a CD-ROM, DVD, local area network, or the Internet, has a high initial development cost and a high upkeep cost. Sometimes the course development is paid for by research and development funds provided by federal or private foundation grants. Sometimes the course development is paid for by the intended user group, such as the military. And, sometimes the course development is paid for by a commercial for-profit or non-profit company.

The economics of such instruction tend to work out in situations where the traditional mode of instruction is quite expensive and/or involves unacceptable levels of risk. We see this in airplane pilot training, training of spaceship crew, and many aspects of military training.

There is one more really important aspect of HIICAL. When engaged in this type of learning, the learner has access to a computer and the tools it can provide. That is, this type of learning environment can readily incorporate the powerful ICT tools paradigm from the previous chapter. The result is that students learning in an environment that includes routine use of powerful ICT-based tools integrated into an HIICAL environment. Truly, this would represent a major paradigm shift in education.

A Speculative Scenario of Federal Government Funding

This section contains my musings about a future in which the US Federal Government makes a long term commitment of a billion dollars a year for the development and distribution of a relatively large number of HIICAL courses. In a “mass production” mode, it would be possible to develop quite high quality year-length courses at a cost of perhaps \$5 million each that could be accessed via the Web, local area school networks, and on DVDs. Such courseware could then be provided free to schools and individual students.

To give you the flavor of such an idea, suppose it costs \$5 million to develop a course, that \$1 million a year is used to maintain and improve the course, and that a course has a life of five years before it is discarded or is completely redone at a cost of \$5 million. Then the total cost for having the course available for five years of student use is \$10 million.

If just 100,000 different students used the course each year (so that over a period of five years a course gets used by a half million different students), this would amount to a cost of \$20 per student. If twice as many students used a course, the Federal Government’s cost per student would be \$10.

The astute reader will notice that I have not included distribution costs. Distribution would all be done electronically via the Web, as would all of the updates. Thus, the cost of distribution would be modest. (Indeed, just to speculate a little, I suspect that some existing for-profit companies might well be willing to do the distribution free, as long as they were allowed to sell ads that would be seen by users of the download sites.)

In addition, this fiscal analysis does not include costs of providing students access to computers that can run the courses. At the current time, about three-fourths of students have access to a computer at home that would be adequate to the task. On average, schools in the US have about one microcomputer per five students that would be adequate to the task. My vision of the future is one in which all students will have appropriate access to computers at school and home. At the current time, some schools and school districts and providing students with laptop computers that they carry from class to class and take home.

Roughly speaking, the US has about 50 million students in public and private schools at the precollege grade level, or about 4 million students per grade level. The 100,000 or 200,000 student course-uses per year used in the above example is 2.5% to 5% of the students at one grade level in this country.

At this point my might say “Hmmm.” This sounds like a good project to be funded by our Federal Government. Suppose that the US Federal Government made a long -term commitment of a billion dollars a year to support the development and free distribution of asynchronous HIICAL distance learning materials. With the relatively low enrollment of 100,000 students per course per year, this would provide enough courses for every student to take one course per year. If enrollments were twice as high, every student in the country could take two such courses per year. If distribution is mainly done electronically (with schools and students being allowed to make copies of the material onto DVDs) then the increased use of the courses would the Federal Government very little.

I enjoy playing with this type of math and developing spreadsheet models to allow me to ask and answer “What if?” types of questions. In the model that I like to play with, I include some funds for distribution and a low level of consulting on downloading problems. I estimate that a billion dollars a year would provide for eventually having about 400 different yearlong courses available.

Of course, a key issue is who would develop and maintain the courses. I can imagine the Federal Government putting out a request for proposals, with the intent of funding a number of centers at \$25 million a year. In my model, eight centers would be created each year, each receiving a five-year \$125 million grant. Thus, over a period of five years, 40 such centers would be created. When a center’s grant ran out, it could compete for a new round of funding. In this model, the idea would be to create completion among the various organizations (non-profit companies, for-profit companies, research centers, universities, and so on) that were qualified to undertake such large curriculum research, development, implementation, and evaluation activities.

The idea of large federal funding for CAL is not new. Terrel Bell was the 1981-1984 Secretary Education under President Ronald Reagan. At one point, Reagan agreed to and backed a proposal from Bell to invest \$100 million a year in CAL. Later Reagan changed his mind, so this program did not move forward.

In the year 2003-2004, the total cost of K-12 public and private education in the United States was about \$500 billion (K-12 Funding, n.d.). Thus, an investment of a

billion dollars a year is equal to two-tenths of one percent of the cost of K-12 public education. In the year 2003-2004, the US Federal Government spent a little over \$40 billion on K-12 education. Thus, an investment of a billion dollars a year is about 2.5 percent of the amount the federal government is currently spending on K-12 education.

Based on the above types of analysis, here is my long range forecast for a major paradigm shift in precollege education. Over the long run, HIICAL delivered by a combination of the Web, local area and wide area networks, and portable media such as DVD and its future replacements, will become a commonplace additional to schooling at the precollege level in the US and in many other countries. This will have three effects:

1. Learning outcomes produced by educational system will be significantly improved. Students will learn more, and they will learn it better. They will learn in an environment that includes routine use of powerful ICT tool as an aid to solving problems and accomplishing tasks.
2. Productivity of precollege education, as measured by the inflation-adjusted cost of personnel, will be substantially improved (meaning, personnel costs will decline).
3. The job of being a precollege teacher will change significantly as schooling becomes much more learner-centered.

Concluding Remarks

Remember Peter Drucker's forecasts about increasing productivity in education, especially at the elementary school level. HIICAL holds great potential for substantially increases in learner productivity (learn more and better, in less time) as well as in teacher productivity HIICAL can be delivered in a distance learning mode via the Internet.

A key aspect of HIICAL is that it can incorporate researcher and practitioner knowledge of effective curriculum design, instructional processes, and assessment. Moreover, this environment is consistent with the appropriate integration of ICT content into the curriculum content. It is clear to me that the future of schooling (formal education) will be thoroughly intertwined with such HIICAL.

Personal Growth Activities for Chapter 8

1. Reflect on some of the paradigm shift ideas from this chapter. Which ones seem most appealing to you, and which ones "rub you the wrong way?" Why?

Activities for Chapter 8

1. Select one of the forecasts given in this chapter. Suppose that you were absolutely convinced that this is highly accurate forecast. What might you do during the next few years of your professional career to take advantage of this forecast?
2. Repeat (1) for a second forecast given in this chapter.
3. Consider the content and forecasts of this chapter. If the forecasts prove to be reasonably correct in the next two decades, how will teaching jobs be changed.

Chapter 9: Inventing the Future for an Individual Classroom Teacher

Opportunity is missed by most people because it is dressed in overalls and looks like work. (Thomas A. Edison)

People learn in response to need. When people cannot see the need for what's being taught, they ignore it, reject it, or fail to assimilate it in any meaningful way (Brown & Duguid, 2000)

The first chapter of this book indicated that each individual invents part of their future. This chapter assumes that you are an ordinary or extraordinary classroom teacher, and that you want to invent the future of ICT in your classroom. The chapter provides you with an outline and some guidance, but you will need to do most of the work. After all, it is **your future** that you are inventing!

Six Areas for Personal ICT Long-Range Strategic Planning

As a teacher, you wear many hats. However, this chapter focuses on just six of them, and all are examined from an ICT point of view. We have named these six hats *Personal Goals* (PG). In the list given below, these goals are stated in the form of goals achieved. Of course, you will need to decide for yourself the level of expertise that you want to achieve in each of these PG areas. Indeed, you may decide that you have no interest in achieving some of these goals. However, my hope is that you are convinced that work toward each of these goals will enhance your professional career and improve the quality of education that your students receive.

PG1. Curriculum. Your curriculum content is appropriately reflecting ICT as part of the content of each discipline you are teaching and as a routine, everyday tool that students use much in the same manner as they use other basics such as the 3Rs.

ICT cuts across all disciplines. As a teacher, you are responsible for helping students to gain fluency in ICT at the grade levels and in the disciplines that you teach. This is akin to the responsibility that you have in “writing across the curriculum” and in “higher-order thinking and problem solving” across the curriculum. You may also have responsibility for helping students to gain initial fluency in use of one or more ICT tools (especially if you teach at a primary school level) or to learn ICT as part of the specific discipline(s) you teach (especially if you teach at a middle or secondary school level).

PG2. Instruction (Pedagogy). Your instructional processes are making appropriate use of the ICT aids to teaching and learning.

ICT has brought teachers a number of new instructional aids and students a number of new learning aids. Within narrow domains, some of these instructional and learning aids are more powerful and effective than the traditional aids. The area of HIICAL provides good examples. Distance Learning is a steadily increasing vehicle for delivery of instruction.

PG3. Assessment. Your formative, summative, and long term retention assessments of your students are making appropriate use of ICT aids to assessment and appropriately assesses their increasing ICT knowledge and skills.

There are two distinct issues. One is roles of ICT in improving the quality (valid, reliable, fair, authentic), timeliness, and value (to your students and to yourself as a teacher) of assessment of your students. The other is assessment of the ICT aspects of the curriculum you are teaching.

PG4. Productivity. Your professional productivity is being enhanced by making appropriate use of ICT aids in curriculum, instruction, and assessment, and in other areas such as lesson planning, doing research to support your work, communicating with parents, preparing needed reports (such as grade reports), and so on.

This book contains a strong emphasis on increasing the productivity of in various aspects or components of our education system. We have explored some ideas of students learning more relevant content, and students learning more, better, and faster. We have explored some ideas of making education more capital intensive and less labor intensive. We have even briefly discussed the “far out” idea that eventually students may have personal robots that serve both as caretakes and thsat routinely interact with “their”student in an HIICAL mode.

PG5. Professional Growth. Your professional growth—what you do to maintain and increase your professional expertise—is being enhanced by appropriate use of ICT.

This book has stressed that the future will be one of continued rapid improvements in ICT and the field of ICT in education. ICT is an area in which you need to develop an appropriate level of expertise, and it is an aid to lifelong learning in all disciplines. It is a powerful aid to communicating with your professional colleagues and carrying on other aspects of developing your professional career.

PG6. Leadership. You are continuing to develop your leadership potential and are playing an active ICT in education leadership role. You are looking toward the future of ICT in education, staying ahead of the curve in ICT in education learning and implementation, and increasing your contributions to improving your school and school district.

Many teachers are uncomfortable with their current professional knowledge of ICT in education. In essence, they sense that they are behind the learning curve—that the field is pulling away from them. Such teachers tend to take a defensive position, or even a negative position, in terms of use of ICT in their classrooms and in their school. Others see ICT as an opportunity for personal professional growth and for developing a leadership role in their schools. They like the challenge of being closer to the leading edge of ICT in education than their fellow teachers.

Personal Long-range Strategic Planning

In the next six sections of this chapter, we will go through the six steps (from Chapter 4) of the strategic planning process. The goal is to help you to develop some sample goals and objectives from the six Personal Goals listed in the previous section.

To begin, consider the table in Figure 9.1, with one set of headings being the six PGs from the previous section, and the set of headings being the six steps for Long-Range Strategic Planning. Your goal is to complete the 7th column—to develop and implement a component of your personal Long-Range Strategic Plan in each of the six Personal Goal areas.

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Your Personal LRSP
PG1	----->	----->	----->	----->	----->	----->	
PG2	----->	----->	----->	----->	----->	----->	
PG3	----->	----->	----->	----->	----->	----->	
PG4	----->	----->	----->	----->	----->	----->	
PG5	----->	----->	----->	----->	----->	----->	
PG6	----->	----->	----->	----->	----->	----->	

Figure 9.1. Personal Goals planning table.

What you need to do is to carry out Steps 1-6 for each Personal Goal. You will rewrite each PG so that it is specific to you, and you will develop objectives to support your PGs. All of these goals and objectives will be carefully integrated so that, as a whole, they make sense to you. You will develop details of a long-range strategic plan to accomplish the goals and objectives. The result will be your own personal Long-Range Strategic Plan for ICT in your professional life.

When Long-Range Strategic Planning is being carried out by a committee, much of the planning committee's time is spent in communication and negotiation. When you are the entire committee and you are the person who will implement the plan, the situation is vastly simpler. Thus, it can proceed more rapidly. Still, however, the process requires careful thought over an extended period of time.

1. Evaluate the Situation

Evaluating the situation is a combination of data gathering and analysis, and introspection. You need to develop answers to question such as:

1. What is my current level of expertise (knowledge and skills) in ICT in each of the six PG areas given in the previous section, and how have these levels of expertise changed over the past year or so?
2. What is my current level of use of ICT in each of the six PG areas given in the previous section, and how have these levels of use changed over the past year or so?
3. What ICT facilities are available for my personal use at home, within my classroom, and in school areas restricted just to staff?
4. What are the ICT levels of expertise of my students? (Probably they vary widely.)
5. What ICT facilities are available for my students' use at school, at their homes, and in the community?
6. What do my students, fellow teachers and administrators, and the parents of my students think about and know about the use of ICT in education?
7. What is the status of ICT Long-Range Strategic Plans for ICT in education at my school and in my school district? Do plans exist, and how well are they being implemented?
8. What are other things that I need to know about the current situation so that I have an appropriate foundation as I proceed in developing my personal Long-Range Strategic Plan? For example, you might want to determine answers to questions 1 and 2 for your fellow teachers in your school building and in other schools in your district.

As you proceed in steps 2-6, given below, it is quite likely you will need to return to **(1. Evaluate the Situation)** to gather and analyze more current situation data.

2. Articulate a Vision

Articulating a vision is a free ranging, brainstorming activity. The previous chapters in this book have given you increased insights into some and future capabilities of ICT in education. For each of the six PG areas, what is your 15-year vision of what you will be doing and what you will be like?

Remember, this aspect of Long-Range Strategic Planning does not worry about the feasibility of achieving the vision. However, it is grounded in your current knowledge about education and ICT.

Write at least one visionary statement for each of the PG areas. For example, perhaps in the PG5 (Professional Growth) area you have a vision of yourself as being in charge of ICT in your school or your school district. Don't be afraid to have a lofty vision. Some school districts now have an Assistant Superintendent for ICT.

3. Decide on a Mission Statement

A mission statement is short statement that provides you with an overriding, unifying sense of direction. It provides a sense of direction as you begin to work on developing specific goals and objectives. A mission statement should be short, easy to understand, and easy to communicate to others. Here are four quite different examples. My mission is:

1. To be a school and district ICT leader and exemplar who is making a continuing high level contribution to improving education in my school district through appropriate use of ICT.
2. To be as ICT-competent in my professional work as I am in the other aspects of my professional work.
3. To position myself in the middle of the pack in terms of use of ICT in my professional work.
4. To “hang in there” and keep a low ICT profile until I retire.

You need to develop a mission statement that is pleasing to you (you have ownership, you are intrinsically motivated) and that has the characteristic that you can tell when you are making progress on achieving the mission.

For example, suppose that you have decided on a mission of “Boldly going forth to become the technology facilitator in my school or another school in my town.” (Perhaps you are a Star Trek fan and like the idea of boldly going....) To get yourself ready for the next big step in developing your LRSP, you might want to some additional evaluation of the current situation. For example, you might want to talk to and/or job shadow a couple of school technology facilitators.

4. Propose and Select Goals and Objectives

Now you have a mission that is consistent with your visionary goals. Your next step in developing your LRSP is to develop a set of quite specific and measurable goals that are designed to achieve your mission. Typically each goal will be supported by two or three objectives or sub goals.

Proposing and selecting goals is a concrete and relatively difficult step that requires careful analysis and reflection. The six PGs given at the beginning of this chapter will likely be useful. However, now is the time to rewrite each one so that it more specific to your particular mission. Here is an example based on the mission of “Boldly going forth to become the technology facilitator in my school or another school in my town.”

- G1. Curriculum: I will learn ICT well enough to thoroughly and routinely integrate ICT into all of the curriculum content that I teach. I want my students to become skilled at using the tools and knowledge from ICT that are useful in representing and solving the problems in the areas that I teach.

- G2. Instruction: I will learn to make effective use of ICT as an aid to my teaching and as an aid to my students' learning. I will routinely make effective use of ICT in my instruction and my students will routinely make effective use of ICT as an aid to learning.
- G3. Assessment: I will increase my focus on authentic assessment, with special emphasis on assessing students in their routine, everyday environment of ICT use.
- G4. Personal productivity: I will carefully examine ICT uses that might contribute to my personal productivity as an educator. I will implement those uses that specifically increase my productivity and effectiveness as an educator.
- G5. Professional growth: I will develop and enhance my skills in helping my fellow teachers to learn about and effectively use ICT in their teaching and other aspects of their professional lives.
- G6. Leadership: Leadership: I will move myself closer to the leading edge of ICT in education than anyone else in my school, and I will begin to develop a reputation as an ICT in education leader in my school.

5. Develop a Strategic Implementation Plan

Your strategic implementation plan says what you will do to achieve each of your goals. You should include enough detail so that the plan provides you with a clear sense of direction and how to use your time and other resources.

Here is an example based on the overall mission of becoming a school technology facilitator and the six goals listed in the example of the previous section. In this example, P1.1, P1.2, etc. are specific pieces of a "Plan" designed to accomplish Goal 1, and so on.

- G1. Curriculum: I will learn ICT well enough to thoroughly and routinely integrate ICT into the content of the curriculum that I teach. I want my students to become skilled at using the tools and knowledge from ICT that are useful in representing and solving the problems in the areas that I teach.
 - P1.1 I will begin to experiment with giving my students assignments that require use of ICT, such as word processing a report, using the Web, communicating via email, turning in an assignment as an email attachment, and so on. I will introduce one "new" idea of this sort each month, and I will have students use the ICT idea enough times so that I believe they have developed a usable level of knowledge and skill.
 - P1.2 Each time I introduce a new unit in my courses, I will facilitate a class discussion on what students think are current roles of ICT in solving the problems, accomplishing the tasks, and "knowing and making use of" the topic of the unit.
 - P1.3 Each summer I will thoroughly analyze about one-third of the curriculum content that I teach, and I will update it by integrating appropriate up to date ICT content.
- G2. Instruction: I will learn to make effective use of ICT as an aid to my teaching and as an aid to my students' learning. I will routinely make effective use of ICT in my instruction and my students will routinely make effective use of ICT as an aid to learning.

- P2.1 I will immediately begin using a computer projection system in my everyday classroom.
- P2.2 The first workshop I take this year will be on creating a Website. As soon as I learn how to create a Website, I will develop a site that is a start on helping to meet some of the information needs of my students. The first content will be course descriptions, expectations, and assignments.
- P2.3 Eventually my Website will contain a “Good Content Resources on the Web” section for each course I teach. The Web resources that I select will be ones that are appropriate to my students. I plan to create the first version of this resource this year. After that, each year I will review the resources to see if they are still available and relevant, and I will add some new resources.
- P2.4 Eventually my Website will contain a “Good ICT-Based Instructional Materials” section for each course that I teach. These sections will focus on software that is available on the Web for no-cost use, and software that my school or school district is making available for student use. I plan to create the first version of this resource next year. After that, each year I will review the resources to see if they are still available and relevant, and I will add some new resources.
- G3. Assessment: I will increase my focus on authentic assessment, with special emphasis on assessing students in their routine, everyday environment of ICT use.
- P3.1 I know some of the basic ideas about authentic assessment, but I know I don’t do authentic assessment of student ICT knowledge and skills in my teaching. During the next three months I will make an individual observation of a representative sample of my students as they use ICT, and I will write myself a brief summary of my findings.
- P3.2 During this year, I will try out the idea of including one “more authentic” question on each major test I give my students. These will not be just ICT questions—my intent is to learn more about how to make up authentic test questions in general, and how my students deal with such questions.
- G4. Personal productivity: I will carefully examine ICT uses that might contribute to my personal productivity as an educator. I will implement those uses that specifically increase my productivity and effectiveness as an educator.
- P4.1 My school district has a site license for an electronic gradebook, and I have several friends who use it. I will have one of my friends help me to learn how to use this electronic gradebook and then I will use it regularly.
- P4.2 I already use a word processor to make the handouts I use in my classes. However, I am not very systematic in naming and saving them in a manner that so that I can easily find them the next year, and I don’ regularly update the handouts immediately after I see how well they work with students. I will correct both of these “flaws” in my behavior.
- P4.3 After I get my Website up and running, I will add a sections “Just for Parents.” This will contain information that I want to communicate to my students’ parents. (Of course, I realize that some of my students will also read it. That is one of my intentions.)

G5. Professional growth: I will develop and enhance my skills in helping my fellow teachers to learn about and effectively use ICT in their teaching and other aspects of their professional lives.

P5.1 Each year I will participate in at least two of the ICT workshops provided by my school district.

P5.2 Each year I will attend a state or higher level ICT in education conference.

P5.3 I will join the International Society for Technology in Education and regularly read the publications and Web resources they provide.

P5.4 I will check in with the computer lab teacher (who is also our schools technology coordinator) each time before I take my students to the computer lab. My goal will be to see how I can help in the instruction to be provided and learn how to do it myself.

G6. Leadership: I will move myself closer to the leading edge of ICT in education than everyone else in my school, and I will begin to develop a reputation as an ICT in education leader in my school.

P6.1 I will begin to be more open and assertive in sharing my ICT in education knowledge and skills with my fellow teachers. At least once a week I will facilitate (create) a situation or interaction in which I provide ICT help to a fellow teacher.

P6.2 I will volunteer to be on my school's Technology Committee.

6. Periodic Assessment and Update

A LRSP quickly loses its value unless its implementation is accompanied by ongoing formative evaluation and periodic revision. When you first begin to implement your personal LRSP, it is helpful to keep a diary in which you make brief notes of your activities. You might well do this as a word-processed document on a computer, and make use of a template that includes very brief summaries of your goals and the specific activities in your plan.

Perhaps once a month, browse your diary and create a brief summary of your successes and non-successes. Once a year, thoroughly review, revise, and update your LRSP in a manner that seems appropriate to you.

Concluding Remarks

Consider the following very brief example of use of long range strategic planning:

1. Planning to go to college and then implementing the plan;
2. Planning to become certified as a teacher and then implementing the plan;
3. Planning to find a job as a teacher and then implementing the plan;
4. Planning to remain in teaching and then implementing the plan.

If you are a preservice teacher, chances are that you are someplace in (1) or (2). If you are an inservice teacher, perhaps you are in (4). In either case, you have good insight into the time and effort that is required to make and implement serious long-range plans.

The chances are that you know some people who just "go with the flow," sort of drifting along through life. Probably you know others who are very goal-directed. By introspection, you

can likely give an accurate analysis of yourself. If you are not highly satisfied with what you find, think about making a paradigm shift. The Long-Range Strategic Planning process described in this chapter was written using ICT as the focus. However, the same ideas hold for other possible areas of planning.

Personal Growth Activities for Chapter 9

1. Think about the future you would like to invent for yourself in ICT in education. Do you know someone who is a role model for this future or part of this future? If “yes,” think about how you might want to be like this person or people, and how you would like to be different from this person or people. If “no,” think about what this “no” tells you about yourself and your current environment.

Activities for Chapter 9

1. Do a modest amount of self-assessment of your knowledge, skills, and use of ICT in education. Identify one of your greatest strengths and one of your greatest weaknesses. Off the top of your head, and assuming you do not make and implement specific plans to change the situation, briefly describe what is most likely to happen during your next year in these two areas.
2. Spend one hour developing a very rough draft start on a personal LRSP for ICT in education. Divide your hour of time up as follows: A) The first five minutes are for introspection and brainstorming, not writing anything down; B) The next 50 minutes are to be spent roughly equally divided among the first six major steps in developing a LRSP; and C) The last five minutes is to be spent in one final quick edit of your document. When you are done, reflect on what you might have done differently and better if you had 10 hours to complete the task.

Chapter 10: Summary and Concluding Remarks

Those who have knowledge, don't predict. Those who predict, don't have knowledge. (Lao Tzu, 6th Century BC Chinese Poet.)

If you can look into the seeds of time, and say which grain will grow and which will not, speak then unto me. (William Shakespeare.)

This final chapter summarizes the forecasts provided in the book and makes a few concluding remarks.

The forecasts in this book can be loosely grouped into three major categories:

1. Forecasts that are related to education or somewhat related to education, but do not talk specifically about ICT or ICT in education.
2. Forecasts about ICT but that do not talk specifically about ICT in education.
3. Forecasts specifically about ICT in education.

Forecasting

The forecasting business tends to include a number of assumptions, and usually few of these assumptions are carefully stated. For example, consider what might the impact be of visitors from outer space showing up next week, and offering us a free copy of a galactic encyclopedia that contains the collected knowledge of the intelligent space-traveling sentient beings of the galaxy? Or, consider what might happen if we have a worldwide epidemic of the ebola virus that wipes out 90% of the earth's population. Or, think about current work on developing drugs to enhance brain functioning. What might the results be if a drug is developed that improves a human brain by a factor of ten? Each would represent a major paradigm shift that few people have thought about or prepared for.

What happens if we begin to experience a developing and continuing worldwide energy shortage or a developing and continuing worldwide food shortage? It is easy to imagine situations that would be so disruptive that they would make this book's discussions about the future sound like silly nonsense.

This book does not attempt to develop forecasts in the various areas mentioned in the previous two paragraphs. Rather, it assumes no major catastrophic changes will occur during the time period of the forecasts. The forecasts assume "business as usual" in scientific and technological progress, and that humans will continue as they have in the past in their efforts to improve education, medicine, life in our society, and so on.

General Forecasts (Not About ICT)

This book contains some general forecasts that help to set the scene for forecasts about ICT in education. Some of these forecasts apply just to ICT, while others are quite general. This section summarizes the some of the very general forecasts given in this book.

Here are a few quotes given earlier in the book:

Productivity [in manufacturing and agriculture in the United States] has increased 50-fold in the last century ... and is growing as fast as ever. [Now] both sectors together employ fewer than one-sixth of the labor force. [...] (Drucker, 1992)

The information superhighway is about the global movement of weightless bits at the speed of light. As one industry after another looks at itself in the mirror and asks about its future in a digital world, that future is driven almost 100 percent by the ability of that company's product or services to be rendered in digital form. If you make cashmere sweaters or Chinese food, it will be a long time before we can convert them to bits. "Beam me up, Scotty" is a wonderful dream, but not likely to come true for several centuries. Until then you will have to rely on FedEx, bicycles, and sneakers to get your atoms from one place to another. This is not to say that digital technologies will be of no help in design, manufacturing, marketing, and management of atom-based businesses. I am only saying that the core business won't change and your product won't have bits standing in for atoms (Negroponte, 1995).

A technological revolution—desktop computers and satellite transmission directly into the classroom—is engulfing our schools. It will transform the way we learn and the way we teach within a few decades. It will change the economics of education. From being totally labor-intensive, schools will become highly capital-intensive (Drucker, 1993, page 194).

We'll see 1,000 times more technological progress in the 21st century than we saw in the 20th. (Ray Kurzweil. PC Expo in June, 2000)

During the lifetime of your students, the world will likely see a factor of more than 100 in the annual growth in accumulation of human knowledge (Moursund, Chapter 1 of this book).

In essence, Peter Drucker's writing over the past decade or so have been forecasting huge gains in intellectual productivity, while Ray Kurzweil is forecasting a much faster pace of technological progress than we have seen in the past. Negroponte's statement captures the essence of an Information Age. Many people have analyzed the rapid growth in the totality of human knowledge, and my quote is merely a rough summary of middle of the road forecasts.

I have not included some of the more speculative forecasts that I have read. For example, Kurzweil forecasts that by the middle of the current century we will have widespread availability of computers that are more intellectually capable than people. I am not quite sure what this forecast means, and I am not able to think very clearly about its implications to people living on earth.

My summary of these general types of forecasts is that our children are growing up in a rapidly changing Information Age society. The pace of change will increase substantially during their lifetimes, so they will see many times as much change as did our parents and grandparents.

Adequately coping with this change—being a productive and responsible adult member of our society—will require ongoing formal and informal education. People who have learned to be effective and efficient learners will have many advantages over those who have not. Our society will have a growing need for people who can deal with novel problems, tasks, and situations.

As a consequence of the types of changes that I envision, there will be a steady increase in the expectations being placed on our schooling system. People will increasingly expect that our schools will be successful in helping students to gain high levels of expertise in solving complex problems, accomplishing complex tasks, and doing other things that require good thinking skills.

General Forecasts About ICT

The ENIAC, which became operational in late 1944, was the first general-purpose electronic digital computer built in the United States. It had about 17,400 vacuum tubes and consumed well over 100,000 watts of power. On average, the tubes each consumed about six watts or power.

Now, imagining living at that time and trying to have a realistic vision of owning carrying around, and routinely using a laptop computer such as the one I currently own. This idea probably would have quickly been rejected, since a vacuum tube-based computer as powerful as

my current desktop machine would consume several tens of billions of watts of power, or perhaps five-percent of the total electrical use of the United States!

But, it was only a few years later that the transistor was invented. In most electronic applications, a transistor can replace a vacuum tube. Less than 60 years of scientific, technological, and engineering progress have led to the current very large scale integrated circuits that contain hundreds of millions of transistors and can be powered by a modest-sized battery. This progress has made it possible for ordinary people to own desktop and laptop computers that are millions of times as powerful as the first electronic digital computers.

I can remember back 25 years ago when microcomputers were beginning to be powerful enough to be “useful” rather than just game machines and toys. It was just a couple of years later that one could first buy a five-megabyte hard drive for a microcomputer—at a cost of \$5,000. Imagine the futurist of 25 years ago thinking about the future of random access storage devices for personal microcomputers. I wonder if such a futurist would have envisioned a disk drive that I looked at when I was shopping last week—a 250-gigabyte hard drive for \$120? The decrease in cost per byte of storage has been by a factor of several million over a period of about 25 years.

Moreover, we have not yet seen the end of rapid change in the storage of digital media. Quoting from WebIndia (2005):

Six leading technology companies have formed a consortium to make an optical disc that could store a few hundred movies.

The Holographic Versatile Disc (HVD) Alliance, which includes Fuji Photo and CMC Magnetics, will let consumers conceivably put a terabyte (1TB) of data on to a single optical disc, reports Cnet news.com.

The consortium said an HVD disc could hold as much data as 200 standard DVDs and transfer data at over one gigabit a second, or 40 times faster than a DVD.

A little over 20 years ago I got a 30 bytes per second telephone modem for my home microcomputer. Now, my home computer DSL connection is more than a thousand times as fast. I can now imagine that eventually I will have a fiber optic connection into my home computer, with a bandwidth of perhaps a thousand times my current bandwidth.

Over the past several decades, capabilities of ICT hardware systems (computer speed, primary memory size, storage capacity, bandwidth) have been doubling every 1.5 to 2 years. Current estimates are that this rapid pace of change will continue for at least another 10 to 15 years or so. The “another 10 to 15 years or so” could well be many more than 15 years, but this is dependent on new technological breakthroughs.

To summarize this section, ICT capabilities have been increasing at a mind-boggling rate for many years, and this is apt to continue for some time to come. Our educational system has not yet learned to make effective use of the current ICT capabilities. Thus, there is plenty of room for progress without assuming any further growth in ICT capabilities. When we consider the continued rapid growth in ICT capabilities, we see that our educational system faces an uphill struggle.

Forecasts About ICT in Education

Looking backwards, we can see how the development of agriculture changed the societies of our world. We can see how the United States has changed—in a period of about 225 years—from a nation of farmers to a nation in which less than three-percent of the workforce is able to produce a nationwide surplus of food

Looking backward, we can see how the industrial revolution has changed the societies of the world. We can see that productivity per industrial worker has increased by a factor of 50 or so over the past hundred and fifty years.

Looking backward, we can see significant changes in our society occurring during the first 50 years of the information age. We can see how the various components of the ICT industry have grown and increased substantially in productivity.

All of these things notwithstanding, we are still at the early stages of the information age. And, ICT has had only a modest impact on the instructional components of our educational system.

The invention or development of a new physical body or mental tool creates both opportunities and challenges. In brief summary, new and better ICT tools:

1. Help us to “better” solve some problems and accomplish some tasks that we are currently addressing without the new tools. Here, the term “better” may have meanings such as: in a more cost effective manner; faster; more precisely; more reliably; with less danger; and so on.
2. Help us to solve some problems and accomplish some tasks that cannot be solved without the new tools.
3. Create new problems. For example, our educational system is faced by the problem of deciding what students can and should learn about ICT, and how to provide the necessary aids to accomplishing ICT-related learning goals. Our society is faced by the problems that come along with genetic engineering and cloning.

The ICT in education forecasts in this book paint pictures of some of the possibilities. For example:

- Curriculum, instruction, and assessment will take place in an environment in which all students have routine access to very powerful ICT systems and use them routinely, much in the manner that students use pencil, paper, and books today.
- HIICAL distance learning will become commonplace, a routine everyday component of the instructional and learning process. This HIICAL will include a curriculum in which ICT tools are routinely used.
- The content of each discipline taught in schools will appropriately reflect ICT as an integral and important part the way that problems and tasks are represented and solved or accomplished in the discipline.
- ICT will grow in importance as a basis of interdisciplinary and discipline-specific tools, and also as a discipline in its own right.
- ICT will become a routine aid to teachers and other educators in the non-teaching aspects of their professional careers, and will significantly increase their personal productivity in these areas.

These and other aspects of ICT in curriculum, instruction, assessment, and the everyday professional lives of educators will facilitate significant increases in productivity. For the most part, however, these gains in productivity will not be like the gains in worker productivity experienced in agriculture and industry over the past century and more. For example, we cannot

look at students as “workers” and then project that we will need only 1/50 as many workers of this sort. That makes relatively little sense.

However, it does make sense to forecast that on average students will get a much better education in the future. We know that much improved learning is possible just by looking at the results of students having good teachers and/or good one-on-one tutoring. We see good signs of how ICT can make a significant contribution to the teaching and learning processes, for example through HIICAL.

It also makes sense to predict that the nature of a teacher’s job will change significantly. I think that three aspects of this will be:

1. The will become more of a guide on the side, as contrasted with being a sage on the stage. The teacher will become more of a facilitator of learning and less of a fountain of knowledge of what is to be learned.
2. There will be a gradual but steady increase in use of HIICAL systems that are better aids to student learning than are the current teacher-with-classroom-full-of students.
3. Teachers will learn to work effectively with ICT systems as an aid to teaching and learning, rather than competing with such systems.

Concluding Remarks

If forecasts of increasing power of ICT systems prove to be correct, then today’s toddlers will be graduating from college into a world that has lots of robots that have enough “intelligence” to carry out a wide range of jobs that are now filled by humans. These will not be intellectual jobs, requiring the type of thinking and complex decision making that we associate with well-educated humans. Rather, they will require a very modest level of thinking and decision-making.

The gradual development of such robots and other artificially intelligent machines will put increasing pressure on our educational system. I think that this will be a really “fun” time to be involved in education. There are tremendous challenges, and there are tremendous possibilities.

The possibilities are fueled by progress in the craft and science of teaching and learning—including educational research and brain science. ICT is a powerful aid in much of this research, and it is a powerful aid in implementation of what we are learning from the research.

You, an individual preservice or inservice teacher, are poised to move into and be a part of the future of education. Enjoy!

Personal Growth Activities for Chapter 10

Think about the aspects of teaching that are the most fun to you, and the aspects that are less fun. Think about how the fun and the not-so-fun activities will be impacted by ICT over the next decade or two. Share your thinking—your pleasant thoughts and your fears—with some of your friends.

Activities for Chapter 10

1. Select some important aspect of the future that is not covered in this book. For example, you might pick environment, energy, food, or so on. [For energy, perhaps you will want to start at US DOE Office of Energy Efficiency and Renewable Energy <http://www.eere.energy.gov/>.] Analyze how your topic relates to education and to being a

teacher. Read what the futurists have to say about your topic, and analyze how the job of a teacher might change if their predictions prove to be correct.

2. This book is relatively short and limited in both breadth and depth. Suppose that you could talk the author into adding another chapter. Briefly outline the topics you would like the chapter to cover and why such a chapter would be an important addition to the book. I'd appreciate it if you would then email your suggestions to me at

Appendix A: Technology

It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of organization of labor and the distribution of goods—in order that the creations of our mind shall be a blessing and not a curse to mankind. Never forget this in the midst of your diagrams and equations. (Albert Einstein, in an address at Cal Tech, 1931.)

Technology is much more than just computer technology or Information and Communication Technology (ICT). Since this book is only about ICT in education, it is important to distinguish between ICT and other technologies. Nowadays that is not easy to do, as ICT is an important aspect of almost all science and technology.

The appendix draws on a information from the International Technology Education Association (ITEA) and the International Society for Technology in Education (ISTE).

Science and Technology

Some people use the words “science” and “technology” interchangeably. Thus, we begin by examining definitions of these two words. The following definitions are quoted from Encarta® World English Dictionary © 1999 Microsoft Corporation.

sci·ence n

1. the study of the physical world and its manifestations, especially by using systematic observation and experiment (often used before a noun)
2. a branch of science of a particular area of study
3. the knowledge gained by the study of the physical world
4. any systematically organized body of knowledge about a specific subject
5. any activity that is the object of careful study or that is carried out according to a developed method

tech·nol·o·gy n

1. the study, development, and application of devices, machines, and techniques for manufacturing and productive processes
2. a method or methodology that applies technical knowledge or tools
3. the sum of a society's or culture's practical knowledge, especially with reference to its material culture

As you can see, science and technology are not the same thing. However, the two fields are closely related. In simple terms, one might think of science and technology as being related in the way that theory and practice are related. In education, for example, we talk about the “science and craft” of education, or the “theory and practice” of education. There is an ongoing struggle to translate educational research (educational theory) into effective practice.

Similarly, engineers need to be versed not only in the underlying theory (the science) of the problems they are addressing, but also in the design and development of machinery to help solve

the problems. An engineering school provides its students with a careful blend of theory and practice.

A somewhat different way of viewing the situation is to look at the Liberal Arts versus the Professional Schools in a university. A Professional School tends to place its greatest emphasis on the applications of the field to representing and solving real world problems. Of course, it places some emphasis on the underlying theory. A department in Liberal Arts tends to take the opposite approach. It places the greater emphasis on the underlying theory and less emphasis on applications of the theory.

International Technology in Education Association (ITEA)

Quoting from the ITEA Website (ITEA, n.d.):

The International Technology Education Association is the largest professional educational association, principal voice, and information clearinghouse devoted to enhancing technology education through experiences in our schools (K-12). Its membership encompasses individuals and institutions throughout the world with the primary membership in North America.

...

ITEA represents more than 40,000 technology educators in the U.S. alone who are developers, administrators, and university personnel in the field representing all levels of education.

...

Broadly speaking, technology is how people modify the natural world to suit their own purposes. From the Greek word *techne*, meaning art or artifice or craft, technology literally means the act of making or crafting, but more generally it refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants. (Excerpt from Standards for Technological Literacy, ITEA, 2000)

There are many definitions of technology and many misrepresentations of what technology is meant to be. Below you will find the terms and definitions that we use in order to discuss this widely misunderstood term.

Technology--1. Human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities. 2. The innovation, change, or modification of the natural environment to satisfy perceived human needs and wants.

Technological Literacy--The ability to use, manage, understand, and assess technology.

Technology education--A study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities.

International Society for Technology in Education (ISTE)

Although ISTE's name suggests that the organization deals with all of technology in education, it actually focuses only on ICT in education. Within that broad field, it mainly focuses on ICT in precollege education and in teacher education.

In recent years, ISTE has developed National Educational Technology Standards (NETS) for PreK-12 students, for teachers, and for school administrators (ISTE NETS, n.d.). The general standards for students are quoted below. Wherever you see the word "technology" in this quoted material, think of "information and communication technology" or "computer technology."

1. Basic operations and concepts
 - Students demonstrate a sound understanding of the nature and operation of technology systems.

- Students are proficient in the use of technology.
2. Social, ethical, and human issues
 - Students understand the ethical, cultural, and societal issues related to technology.
 - Students practice responsible use of technology systems, information, and software.
 - Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
 3. Technology productivity tools
 - Students use technology tools to enhance learning, increase productivity, and promote creativity.
 - Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.
 4. Technology communications tools
 - Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
 - Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.
 5. Technology research tools
 - Students use technology to locate, evaluate, and collect information from a variety of sources.
 - Students use technology tools to process data and report results.
 - Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.
 6. Technology problem-solving and decision-making tools
 - Students use technology resources for solving problems and making informed decisions.
 - Students employ technology in the development of strategies for solving problems in the real world.

Appendix B: Goals of Education in the United States

The principle goal of education in the schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done; men and women who are creative, inventive and discoverers, who can be critical and verify, and not accept, everything they are offered. (Jean Piaget, 1896–1980)

Chapter 3 contains David Perkin’s list of three very general, unifying goals of education:

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

The appendix contains a more detailed list of goals of education. It is a list of goals that many people in American society generally agree upon. Each of the goals is followed by brief comments that about how the goal is being affected by ICT.

The list has been divided into three categories—Conserving Goals, Achieving Goals, and Accountability Goals. In most societies, education has a major goal of conserving and preserving the culture and values of the society. Interestingly, this tends to create some stress between Conserving Goals and Achieving Goals. As students gain increasing knowledge and skills, they sometimes rebel against the conservative nature of schools and their society.

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: In recent years 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 Internet and 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 expected to use email and the Web in a responsible manner.

G2 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 ICT. Our educational system must allow for such differences in values. In some 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.

G3 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 ICT 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 email. It has become common for students to develop hypermedia documents as an aid in disseminating the results of their studies.

Achieving Goals

G4 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. Achieving full potential includes learning to make effective use of contemporary tools that are used in the fields where one is developing their potentials.

G5 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 ICT is a basic skill. A number of states have set goals for having all of their students to gain basic knowledge and skills in use of a variety of ICT tools.

G6 General Education: All students have appreciation for, knowledge about, and understanding of a number of general areas of education, including:

- Artistic, intellectual, scientific, 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: ICT is part of the technical accomplishments of humanity. ICT is now a valuable aid to learning and using one’s knowledge in each of the areas listed above.

G7 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: ICT will continue to change quite rapidly. This will present a learning challenge to students of all ages throughout their lifetimes. However, ICT is becoming an increasingly powerful aid to learning for learners of all ages.

G8 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: ICT is a powerful aid to problem solving in every academic discipline

G9 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: ICT, including the Internet, cell telephones, and the Web, is fast becoming a routine component of life in our society.

G10 Social Skills: All students interact publicly and privately with peers and adults in a socially acceptable and positive fashion.

Comment: ICT has brought us new forms of communication and social interaction, including desktop conferencing, picture phones, email, chat groups, and groupware.

G11 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: ICT is both a discipline in its own right and a driving force for change in many different areas of technology, science, and research.

Accountability

G12 Assessment: The various components of an educational system that contribute to accomplishing the goals (such as those listed above) are assessed in a timely and appropriate manner to provide formative, summative, and long term impact evaluative data that can be used in maintaining and improving the quality of the educational system.

Comment: Accountability and assessment are thoroughly intertwined. In the past two decades, the issue of authentic assessment has received a lot of attention. As ICT is more thoroughly integrated into curriculum content, the assessment (authentic assessment) of this student learning becomes a new challenge to an educational system. Electronic portfolios are gradually increasing in importance as an aid to authentic assessment.

G13 Accountability: All educational systems are accountable to key stakeholder groups, including:

- Students stakeholders
- Parents and other caregivers of the students
- Employees and volunteers in educational systems
- Voters and taxpayers

Comment: Communication amongst and between stakeholders is an essential component of accountability, and ICT is a powerful aid to communication.

Appendix C: Goals for ICT in Education

Information on its own is not enough to produce actionable knowledge... Looking beyond information, as we have tried to do, provides a richer picture of learning. Learning is usually treated as a supply-side matter, thought to follow teaching, training, or information delivery. But learning is much more demand driven. People learn in response to need. When people cannot see the need for what's being taught, they ignore it, reject it, or fail to assimilate it in any meaningful way. Conversely, when they have a need, then, if the resources for learning are available, people learn effectively and quickly. (John Seely Brown & Paul Duguid, *The Social Life of Information*. Harvard Business School Press, 2000)

As you work to invent the future of ICT in education in your classroom, school, or school district, you will likely want to take into consideration a carefully thought out list of goals of ICT in education. This Appendix contains a list of goals for ICT in education. You may want to include some of them, or modifications of some of them, in the future that you are inventing.

ICT Goals

A variety of people and organizations have recognized the need for and value of having widely agreed upon ICT goals for students, teachers, teacher's assistants, and school administrators.

However, ICT is both a complex and rapidly growing field. Thus, goal setters have been faced by the problem of developing and implementing goals that are appropriate to a rapid pace of change. This has led many people to be rather cautious about formulating and attempting to implement rather precisely defined goals for ICT in education.

A significant part of the challenge of such goal setting is to develop goals that will continue to be appropriate as ICT and ICT in education change quite rapidly. As you read this appendix, examine each goal from the point of view of its potential longevity and flexibility.

The 13 goals given here are slight modifications of goals given in Moursund (1997, Chapter 4). A number of these goals were first published in Moursund and Ricketts (1988).

Student Goals—Functional ICT Literacy

The four goals listed in this section serve to define functional ICT 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: ICT literacy, basic level. All students shall be functionally literate in ICT. A basic level of ICT literacy shall be achieved by the end of the eighth grade. It consists of a relatively broad-based, interdisciplinary, general knowledge of ICT applications, capabilities, limitations, how computers work, and societal implications. Here are six specific objectives that underlie this information technology literacy goal.

- A. General knowledge. Students shall have oral and reading knowledge of ICT, and its 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 ICT systems 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 and software. Students shall have basic "dispel the magic" knowledge of the hardware and software of ICT systems. They shall understand the functionality of ICT systems to detect and correct common difficulties, such as various components not being plugged in or not receiving power, various components not being connected, printer out of paper, software not being available, and buggy software.
- 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, probes used to input scientific data, pen-based systems, and voice input.

Goal 2: ICT literacy, intermediate level. Deeper knowledge of computers and other information technology as they relate to the specific disciplines and topics one studies in secondary 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: ICT literacy 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 learning. Telecommunications and other electronic aids are the foundation for an increasingly sophisticated distance learning education system. Education shall use distance learning, when it is pedagogically and economically sound, to increase student learning and opportunities for student learning.

Note that in many cases distance learning 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 shall 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 that 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. 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 ICT 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 Goals

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

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. In more recent years, ISTE has developed three sets of National Educational Technology Standards (NETS). (See ISTE NETS.) These are:

- NETS for Students.
- NETS for Teachers

- NETS for School Administrators

In brief summary, ISTE recommends that a teacher should meet the ISTE NETS for students, be adequately prepared to help students meet the ISTE NETS for Students, and meet the additional goals:

Goal 1: Technology Operations and Concepts. Teachers demonstrate a sound understanding of technology operations and concepts.

Goal 2: Planning and Designing Learning Environments and Experiences. Teachers plan and design effective learning environments and experiences supported by technology.

Goal 3: Teaching, Learning, and the Curriculum. Teachers implement curriculum plans, that include methods and strategies for applying technology to maximize student learning

Goal 4: Assessment and Evaluation. Teachers apply technology to facilitate a variety of effective assessment and evaluation strategies.

Goal 5: Productivity and Professional Practice. Teachers use technology to enhance their productivity and professional practice.

Goal 6: Social, Ethical, Legal, and Human Issues. Teachers understand the social, ethical, legal, and human issues surrounding the use of technology in PK-12 schools and apply those principles in practice.

Appendix D: Miscellaneous Unused Quotations

The strongest memory is not as strong as the weakest ink.
(Confucius, 551-479 B.C.)

I enjoy collecting pithy quotations that seem to be relevant to my writings and thinking. A number of them have been used in this book. This appendix contains quotations that seemed relevant to the book, but that have not been included. They are arranged in alphabetical order, by author.

If you want to see more of my quotations collection, go to <http://darkwing.uoregon.edu/~moursund/dave/quotations.htm>.

Author Not Know

In a few minutes a computer can make a mistake so great that it would have taken many men many months to equal it. (Anonymous)

Author Not Know

Well-informed people know it is impossible to transmit the voice over wires and that, were it possible to do so, the thing would be of no practical value. (From an 1865 editorial in the Boston Post, applauding the arrest of Joshua Coopersmith, who had been attempting to raise funds to develop a telephone. Quoted by Denzil Doyle in *Making Technology Happen*.)

Author Not Know

I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year. (Attributed to the editor in charge of business books for Prentice Hall, 1957.)

Author Not Know

Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools. (1921 New York Times editorial about Robert Goddard's revolutionary rocket work)

Tim Berners-Lee. 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 Jul 96.)

Edmond Burk

You can never plan the future by the past. Letter to a Member of the National Assembly. Vol. iv. p. 55. (Edmund Burke, 1729-1797)

Lord Bryon

The best of prophets of the future is the past. Letter, Jan. 28, 1821. (George Gordon Noel Byron, Lord Byron, 1788-1824)

Jim Clark

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 4 Jun 96 F3.)

Douglas Engelbart

Douglas Engelbart, the man who invented the computer mouse, accepted this year's \$500,000 Lemelson-MIT Prize. As he received the award, Engelbart was described by economist Lester Thurow as "the father of the way we do the Internet, videoconferencing, e-mail and most of our modern interactions with computers. With his help, the computer has become a friendly servant rather than a stern taskmaster." Nicknamed the mouse because connecting wire resembled a tail, the device was patented as an X-Y position indicator for a display system. Engelbart, now 72, says, "In 20 or 30 years, you'll be able to hold in your hand as much computing knowledge as exists now in the whole city, or even the whole world." (AP 9 Apr 97)

Marechal Ferdinand Foch

Airplanes are interesting toys but of no military value. (Marechal Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre)

Galileo Galilei

All truths are easy to understand once they are discovered; the point is to discover them. (Galileo Galilei)

Elbert Hubbard

One machine can do the work of fifty ordinary men. No machine can do the work of one extraordinary man. (Elbert Hubbard)

Lord Kelvin

Heavier-than-air flying machines are impossible. (Lord Kelvin, president, Royal Society, 1895)

John Maynard Keynes

The difficulty lies, not in the new ideas, but in escaping the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds. (John Maynard Keynes)

C.S. Lewis

The future is something which everyone reaches at the rate of 60 minutes an hour, whatever he does, whoever he is. (C.S. Lewis)

Nathan Myhrvold

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 18 Nov 94 p108.)

Henry David Thoreau

Our inventions are wont to be pretty toys, which distract our attention from serious things. They are but improved means to an unimproved end. (Henry David Thoreau, Walden, *Economy*.)

Alvin Toffler

Technology feeds on itself. Technology makes more technology possible. (Alvin Toffler, *Future Shock*, 1970.)

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