A College Student's Guide to Computers in Education

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Abstract

This short book is for undergraduate and graduate college and university students, and for others thinking about enrolling in higher education courses. The information and ideas presented will help you to obtain an education that will be useful to you throughout your life in our rapidly changing Information Age world.

Change is an underlying theme of this book. You are living at a time of a rapid technological change. The rate of change is increasing. Such change brings with it both threats and opportunities. You can shape your informal and formal education to diminish the threats and increase the opportunities.

Gaining a competitive advantage is another underlying theme of the book. Whatever your areas of interest, you can gain a competitive advantage by developing a higher level of expertise in the areas and by developing an increased level of expertise in using computers in the areas. Computer technology is a powerful aid to representing and helping to solve problems and accomplish tasks in every academic discipline.

This book is a companion to *A Faculty Member's Guide to Computers in Higher Education,* which is available free on the Website http://uoregon.edu/~moursund/Books/Faculty/Faculty.html. The two books share many of the same ideas, but these ideas are presented from two quite different points of view.

About Dave Moursund, the Author

"The wisest mind has something yet to learn." (George Santayana)

- Doctorate in mathematics (specializing in numerical analysis) from the University of Wisconsin-Madison.

- Instructor, Department of Mathematics, University of Wisconsin-Madison.

- Assistant Professor and then Associate Professor, Department of Mathematics and Computing Center (School of Engineering), Michigan State University.

- Associate Professor, Department of Mathematics and Computing Center, University of Oregon.

- Associate and then Full Professor, Department of Computer Science, University of Oregon.

- Served six years as the first Head of the Computer Science Department at the University of Oregon, 1969-1975.

- Full Professor in the College of Education at the University of Oregon for more than 20 years.

- In 1974, started the publication that eventually became *Learning and Leading with Technology*, the flagship publication of the International Society for Technology in Education (ISTE).

- In 1979, founded the International Society for Technology in Education). Headed this organization for 19 years.

- Author or co-author of about 50 books and several hundred articles in the field of computers in education.

- Presented about 200 workshops in the field of computers in education.

- Served as a major professor for about 50 doctoral students (six in math, the rest in education). Served on the doctoral committees of about 25 other students.

- Founding member of the Math Learning Center. Served on the MLC Board of Directors since its inception in 1976, and chaired the board for several years.

- For more information about Dave Moursund and for free online, no cost access to 20 of his books and a number of articles, go to http://uoregon.edu/~moursund/dave/.

Table of Contents

Preface

"Fortune favors the prepared mind." (Louis Pasteur)

This book is for students currently enrolled in higher education and students thinking of going to college. It is designed to be read online, although if you want to take the environmentally unsound approach of printing out a copy, I guess I cannot stop you. Many of us find it hard to break old habits, or to replace old habits with new habits.

Over the long run, you will likely gain considerable benefit by learning to be a fluent, online reader. Hardcopy books are not going to disappear during your lifetime or the lifetimes of your children and grandchildren. However, a rapidly increasing amount of the material being published throughout the world will mainly be available online.

Prerequisites for the Reader

The prerequisite computer knowledge assumed in this book includes some experience in using a word processor, email, a browser, and a search engine on the Web. The book is not specifically designed to increase your specific computer-based skills. Rather, it is designed to help you make decisions throughout your educational experiences—decisions that will help you to get a better education.

There is another prerequisite. It is that you have the mental maturity (a level of cognitive development and self-responsibility) to take a high level of responsibility for your own education. **Important question: did you stop and reflect on what the term *cognitive development* means and whether you have a level of mental maturity that is up to the task of reading and learning from this book?** If the expression *cognitive development* is not part of your working vocabulary, look it up on the Web. Take responsibility for your own education!

This Book Tells a Story About Change

Many years ago, you began the long process of becoming a fluent reader. If you are like most students, this was a rather difficult task, taking a number of years before you had a reasonable level of fluency at decoding squiggly marks on a page into meaningful patterns in your brain.

Eventually you began to read *chapter books* (books made up of a sequence of chapters) and you began to learn through the process of reading. The expectation is that typical students can begin to learn by reading by the end of 3rd grade and will be relatively good at it by the end of 6th or 7th grade.

Perhaps during this same time, you began to differentiate in your mind between storybooks and textbooks. A storybook tells a story and is fun to read. A textbook does not seem to tell a story, and most people don't find textbooks particularly enjoyable to read. Not many people select a college textbook for their bedtime reading enjoyment!

During my professional career, I have written many scholarly, academic books. Although each tells a story, I am sure that most of my readers have considered the stories to be "dullsville," and certainly not competitive with a well-written, exciting novel.

The book you are now reading tells a story about the rapidly changing world you live in, and the pursuit of a good education for responsible and successful life in this world.

This story is important to you and your future. As you read this book, think of yourself as the protagonist. Your decision to obtain a higher education is a decision to take charge of inventing your future. This future can take many paths.

Regardless of the paths you pursue in higher education, the world is going to change substantially during your lifetime. Much of this change will be due to changes in science, technology, medicine, environment, population, and other factors that you personally, all by yourself, have little control over.

What you can do is improve your levels of expertise:

- In learning to learn in various disciplines and across disciplines.

- In useable, applicable, knowledge and skills in areas deemed important by you and/or by others.

- In being a responsible adult and lifelong learner.

- In dealing with change and helping others deal with change.

Increasing Your Levels of Expertise

Higher education provides you an opportunity to increase your level of expertise in a variety of different areas. You probably have some goals in mind of what you will do with these increased levels of expertise. Thus, for example, you may be interested in gaining a level of expertise that will help you get a good job, to help you go on to further education, to become a better parent, or to be a leader in helping to solve a variety of global problems. You might want to gain an education that helps prepare to be a more responsible, contributing adult citizen of your rapidly changing community, state, nation, and world.

Computer technology is affecting every academic discipline in a typical institution of higher education. Computer technology is being:

1. Integrated in as part of the content of each discipline, and thus is being a change agent in the content to be learned. Because computer technology is part of the content of each discipline, it is a potential part of one's level of expertise in each discipline.

2. Used as an aid to learning and making effective use of the content of a discipline. Expertise in learning a discipline and expertise in using one's knowledge and skills are both affected by computer technology.

3. Used to augment the capabilities of people's brains.

The book includes a chapter on Human and Artificial Intelligence. Surely, you want to know more about your brain and what recent research is telling us about how the human brain functions. Surely, you want to know what your brain can do better than a computer's "brain," and vice versa. A theme running throughout the book is that of a team consisting of people and their machines (including computers) working together to solve problems and accomplish tasks. A modern education helps to prepare a person to be a productive and valuable member of such a team.

Most of the topics in this book are treated in a relatively easy to read, but scholarly, academic manner. Thus, for example, you will find a large number of items in the References section. Most of the items include links to Websites. The idea is to encourage you to take an increasing level of responsibility for your own education, to develop areas of interest that motivate you, and to get you into a habit of browsing and reading information sources in these areas.

The book contains a relatively extensive Index. One use of such an index is to check and/or review what you have learned by reading the book. After reading this book, look through the entries in the Index. Mentally, do a quick check of each in items of what you know about the topic and what the book has contributed to your knowledge on the topic.

Chapter 1

Introduction

"Before you become too entranced with gorgeous gadgets and mesmerizing video displays, let me remind you that information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all." (Arthur C. Clarke)

Sometimes students think that they can safely skip over the Preface in an academic book, since often the Preface is written mainly for the teacher in a course. In this book, the Preface is mainly intended for students. It is part of the introduction to the book. Thus, if you didn't read the Preface, I recommend that you go back and do so.

Information and Communication Technology (ICT) is a powerful change agent. This chapter expands on the introductory materials presented in the Preface.

Technology and the underlying mathematics and sciences are cumulative, vertically structured disciplines. New developments build on the old. Improvements in transportation and communication make it easier for people to learn about and build upon the previous work of others. Some of the developments, such as the invention of writing, the development of mass produced books, and the computer make significant contributions to speeding up the world's rate of technological and scientific development and scientific. Increasing population and improvements in worldwide education also make significant contributions to the pace of technological and scientific change.

Consequently, you live at a time when the rate of technological change is higher than it has ever been, and when the rate of change is steadily increasing.

Taking Responsibility for Your Own Learning

The fact that you can read and understand this written text indicates that you have a high level of thinking and learning ability. The fact that you are thinking about your current and future education means that you have the wisdom and foresight that I find so appealing in good students. (See the quote from Arthur C. Clarke given above.)

Your decision to begin reading this book indicates that you are inquisitive, and that you are seeking ways to improve your current and future life. Your current level of education and maturity means that you are capable of taking considerable responsibility for your learning now and in the future.

Unfortunately, one of the problems that you may face is overcoming the many years of previous schooling in which others told you what to learn and how to demonstrate your learning. Our precollege education system is slanted toward producing students who say: "Tell me what to learn, how to learn it, and how to demonstrate that I have learned it. Then, I will do what you

have told me to do." In some sense, our educational system tends to take self-responsibility away from students.

Higher education has some propensity to reinforce the concept of *tell me what to do and I will do it.* Consider a different path, a path is called **Being a Responsible Adult Learner.** On this path, you decide what you want to learn. You make use of what you have learned in the past, including what you have learned about how to learn. You focus on strengthening your learning capabilities in areas that interest you. You make use of the myriad of resources designed to help you learn. (College courses are but one of many such resources.) You set your learning goals, and you achieve them at a level that is satisfactory to you.

Being a responsible adult learner is a lifelong challenge. As you and the world you live in change over the years, your learning interests, needs, and capabilities will change. The life of a dedicated, lifelong learner is a challenging, but awesome and rewarding journey.

Information and Communication Technology (ICT) has given us new aids to learning. For example, the Internet is a broad-based network of computer networks, a powerful aid to communication. The Web is the world's largest library, it is growing very rapidly, and it is accessed through the Internet. The Internet and the Web together are a powerful aid to learning. It is important to your future that you become skilled in making use of the Internet and the Web as aids to communication, learning, and making use of your learning.

Writing for Online Reading

You are living at a time that is often called the Information Age. The storage, retrieval, and use of information are more important than ever. We are in the midst of a profound change, going from hardcopy storage to online storage of the collected knowledge of the human race. This change affects authors of academic books such as this one, and it affects readers of such books.

For example, as an author it costs me nothing to publish the book—that is, to make it available free on the Web. It takes only a few minutes to accomplish this task. Moreover, I can readily correct errors and update the book whenever I want.

Publishing online brings another important advantage to authors and readers. As an example, later in this book I will mention a few people who have made profound and lasting contributions to ICT. Raj Reddy of Carnegie Mellon University is an example of such a person. He has been a major world leader in robotics and Artificial Intelligence throughout his long career.

How much more should I say about Raj Reddy? I include him in this book because he is a good example of a person who has made a difference in the world of ICT. However, there are lots of such people. Thus, I certainly don't expect that you will memorize his name and accomplishments, and remember them many years from now.

This person was raised in India, has risen to prominence in the United States and the world, and is working to improve the lives of rural people in India and throughout the world. He is a good example of a *citizen of the world*. Suppose that there is something about what I have said about Raj Reddy that peaks your interests. If so, you can:

- View a video focusing of Reddy's ideas on bringing computer connectivity and technology to poor people in third world countries, http://scil.stanford.edu/video/RajReddy.mov.

- Read his 1995 Turing award talk on Artificial Intelligence (AI). The Turing award is the most prestigious award given by the Association for Computing Machinery. The talk provides an excellent introduction to AI and its future. See http://www.rr.cs.cmu.edu/turing.htm.

- Read about Reddy's Million Book project to get a million books scanned and available free on the Web, http://www.library.cmu.edu/Libraries/MBP_FAQ.html#current. http://www.abc.net.au/rn/science/buzz/stories/s941429.htm http://www.library.cmu.edu/Libraries/LIT/Projects/1MBooks.html

- Get a quick overview of the field of robotics at http://en.wikipedia.org/wiki/Robot.

- Get a quick overview of the field of Artificial Intelligence at http://en.wikipedia.org/wiki/Artificial_intelligence.

- See Raj Reddy's vita and some of his publications at http://www.rr.cs.cmu.edu/rrlong.html.

- Read more about Carnegie Mellon, a world class technology university at http://www.cmu.edu/academics/schools.shtml.

Notice how this shifts the decision of what to learn and how much to learn from me (the author) to you (the reader). If you decide to explore these Web-based sources of information, you will quickly develop an *island of expertise* (a specific, small area of expertise) that likely exceeds that of most or perhaps all of your fellow students and your teachers.

Your exploration of Raj Reddy and his work might lead you to want to know more about Alan Turing—the Turing award is named after him. He was a pioneer in the early development of computers and Artificial Intelligence. There is lots of information about him available of the Web. Google the quoted expression *"Alan Turing"* and you will get more than 900,000 hits.

Why did I tell you to put the search expression in quotes? It is because a search on the unquoted expression *Alan Turing* will produce hits that contain the words Alan and Turing that are not necessarily connected together in the first name, last name order. Notice this "subtle" way that I have attempted to teach you a little about use of search engines on the Web. The Web is the world's largest library, and it is a virtual library. The knowledge and skills that you gain in learning to make effective use of virtual (not hard copy) libraries will be of value to you throughout your lifetime.

Notice that a couple of the references are to materials from the Wikipedia—an online, multi-author, unrefereed, free encyclopedia. There has been considerable brouhaha—especially among teachers—concerning students making use of this unrefereed material. Personally, I find the Wikipedia quite useful and I use it frequently. In addition, it provides an excellent example of cooperative, collaborative writing. Volunteers write it, and the volunteers often rewrite each other's writings.

Helping Yourself to get a Better Education

The goal of this book is to help you get a good education. This is a "self-help" book, in that it is designed to you learn to help yourself get a better Information Age education.

The Raj Reddy example illustrates self-help. As you read that section, you made a decision —based on intrinsic motivation, time pressures, and so on—as to whether you would make use of the Web links that I provided.

Let me give a different, concrete example of self-help. The beginning of this Preface contains the quote from Louis Pasteur: "Fortune favors the prepared mind."

When you read this quote from Louis Pasteur, did your mind "blip" over it, or did you pause to reflect on what this statement might mean, and why this book about computer technology quoted a person who died long before the first electronic computers were built? Did you reflect on your knowledge about Louis Pasteur and how his work has affected your life? Did you consider using a search engine to look up some information about Louis Pasteur? If you looked up some information on the Web, you might have come across:

> If one were to choose among the greatest benefactors of humanity, Louis Pasteur would certainly rank at the top. He solved the mysteries of rabies, anthrax, chicken cholera, and silkworm diseases, and contributed to the development of the first vaccines. He debunked the widely accepted myth of spontaneous generation, thereby setting the stage for modern biology and biochemistry. He described the scientific basis for fermentation, wine-making, and the brewing of beer. Pasteur's work gave birth to many branches of science, and he was single handedly responsible for some of the most important theoretical concepts and practical applications of modern science. (Rhee, 1999)

One of the differences between a storybook and an academic book is the density of ideas. In a storybook, you can skip over quite a bit of the content and still get the gist of the story. It is not expected that you will reflect on the meaning of each paragraph.

In contrast, an academic book is written with the expectation that you will read and reflect. You will actively engage your mind in thinking about how the content of the textbook fits in with what you already know. You will take responsibility for reconciling differences between your current knowledge and skills, and those being discussed in the book. A decision to "blip" even one short sentence is a decision to get less from the book than might otherwise be possible. The main learning that comes from a book such as this occurs though the reader pausing to reflect, do a mental exploration, and perhaps doing additional exploration of an idea.

Assessing Your Current Education

How good has your previous informal and formal education been? Can you self-assess—that is, tell all by yourself how good you education has been?

You can think about the processes of your education, such as the time spent playing sandlot sports, board games, and computer games. You can think about your years in school, the books you have read, the music you have listened to, the video you have watched, and the conversations you have had. You can think about music lessons, sports camps, boy scouts or girl scouts, and so on. All of these are aspects of the process of your informal and formal education.

However, I want you to dig deeper. **How good have the results been** from your point of view and from the point of view of others? How does the quality of your education match up to expectations of your parents, your spouse or a potential spouse, your employer of a potential employer, and so on? How does you education compare with that of your peers? Does your education appropriately prepare you for the overall future that you envision for yourself? Have you learned to take responsibility for your future education and for the challenges of a responsible adult life in a rapidly changing world?

The previous paragraph provides a good example of the challenge of reading an academic book. It is written at about a 10th grade reading level. You can probably read this much text in 20 seconds or so. However, it can take a great deal of time to think about the questions and to explore answers. The paragraph is only useful to you if you spend time in reflecting about your answers.

This reflection process is key to your future informal and formal education. You have reached a level of maturity where you should be taking considerable responsibility for your own education. You have the experience, knowledge, and skills to gain an education that fits your personal needs. Only you can tell if you are achieving these types of informal and formal educational goals.

Your Personal Goals in Education

Before proceeding to the next chapter, stop for a minute and think about your goals in higher education. Here are three areas that might come to your mind:

1. I want to increase my level of expertise in various areas that are in the college or university curriculum. I expect to receive written documentation (transcripts, certificates of accomplishment, diplomas, and so on) that helps provide evidence of my increasing expertise.

2. I want to increase my level of expertise in a number of extracurricular areas (such as social skills, relationships with others, sports, and recreation). In cases where one can accumulate evidence of increased expertise (such as golf handicap or other spots performance), I want to have evidence of my increasing level of expertise.

3. I want my higher education time, expense, and effort to help me increase various areas of expertise more efficiently and effectively than I could in other settings.

Note that your goals in (1) and (2) can strongly overlap. There is no find dividing line between curricular and extracurricular goals and activities. In thinking about (3), be aware that learning goes on all of the time, whether you are in school, holding down a job, raising a family, or vacationing.

As you think about your personal goals in education, think about how you can tell if you are achieving your goals. Robert Sternberg is a world-class expert in human intelligence. He defines intelligence "your skill in achieving whatever it is you want to attain in your life within your sociocultural context by capitalizing on your strengths and compensating for, or correcting, your weaknesses." The reference (Sternberg, 2007) provides access to video (and a transcript of the video) in which Sternberg presents and discusses some of his insights into intelligence.

Whatever goals you have set for yourself, read this book with these goals in mind. This book will prove useful in moving you along the pathway of understanding and achieving your goals,

Summary and Self-Assessment

Each chapter of this book ends with a brief section that mentions a few of the important ideas in the chapter and suggests some ways you can self-assess your understanding of these ideas. Right now, without looking back at the material in the Preface and in this chapter, try to name several ideas from the material that seem important to you.

- If none of the ideas seem important to you, then name an idea that I thought was important enough to emphasize, and do a mental rehearsal of why this idea does not seem important to you.

- If you cannot recall any major ideas from the material, then reflect on how you have spent your time "reading" the material without having any of the ideas actually ending up in your retrievable memory.

Now, go back and quickly browse the headings for the various sections. Select one topic that seems particularly important to you, and select one that seems relatively unimportant to you. Do a mental compare and contrast between these two topics. Do a mental rehearsal of what you would say to me (the author) about ways to improve these two sections, or why one of the sections should be deleted.

From my point of view, the single most important idea in the material is learning to take increased responsibility for one's own education. The message to you is to set some learning goals for yourself, work to achieve these goals, and learn to self-assess your progress in achieving these goals. Of course, I hope that your personal goals will include learning various aspects of ICT!

Chapter 2

Inventing Your Future

"The best way to predict the future is to invent it." (Alan Kay)

"Would you tell me please, which way I ought to go from here?" asked Alice. "That depends a good deal on where you want to get to, said the Cat." (Louis Carroll, Alice's Adventure in Wonderland.)

Please read the "pithy" quotes at the beginning of the chapter and reflect on their possible meaning. Alan Kay has made many very significant contributions to the computer field. His name is closely associated with the development of laptop computers and with the graphic user interface (clicking on icons to make things happen) that is now standard on microcomputers. In 2003, he received the Association for Computing Machinery's Turing Award for his lifetime of contributions to the computer field. His lifetime has, indeed, been one in which he helped to invent the future.

Throughout each day, you make decisions that will impact on your future. From time to time, you make large decisions that you know will have a significant impact on your future. Your decision to pursue higher education is a good example of inventing your future.

Predictions about the future are usually based on having good knowledge about the past and present. Thus, this chapter is based on:

1. Information about the past and present.

2. Some forecasts for the future.

A Little Bit of Computer History

About the time of World War II, the electronic digital computer was developed independently in England, Germany, and the United States. Alan Turing's computer development work in England played an important role in decoding secret German messages, thus contributing substantial to England's war efforts.

More than 50 years ago, in the late 1940s, it was not too clear that computers were here to stay. They were expensive, bulky, unreliable, and difficult to use.

The United States was the third country (after Great Britain and Germany) to begin the commercial production of electronic digital computers. The first commercially produced computer in the United States was the UNIVAC I, delivered in March 1951. Priced in the range of $1.25 million to $1.5 million, the UNIVAC I machine had about 5,200 vacuum tubes, weighed 29,000 pounds, and could perform 1,905 operations per second. Only 46 of these machines were built over a period of about seven years.

The early computers were cost effective on some jobs. For example, in certain types of repetitious calculations—such as payroll— one computer could do the work of many hundreds of people who were using electric calculators. Such massive amounts of computation were also useful in a variety of science and technology situations, such as designing nuclear weapons.

Computer technology has changed a lot since 1951. Much of this change has been made possible by the invention of the transistor. At the time the UNIVAC I was being produced, a vacuum tube cost about a dollar. The transistor had been invented only a few years earlier and initially cost many times as much as a vacuum tube. However, in many electronic circuits, a transistor could replace a vacuum tube, be much more reliable, and use much less power. Moreover, progress in transistor technology soon decreased their price (PBS, 1999).

Adjusting for inflation, in today's dollars the cost of a UNIVAC I was in the range of $8 million to $10 million. Contrast this with today's $1,000 laptop or desktop microcomputer that can do two billion operations per second. A rough calculation indicates that the cost per calculation has gone down by a factor of 10 billion since the early 1950s.

Ten billion! Think about that factor of change. Try to develop a useful level of understanding about this huge number and huge factor of change.

Today's thousand-dollar microcomputer rivals the multimillion-dollar supercomputers of 20 years ago. The torrid pace of improvement in computer price to performance ratio seems likely to continue for a number of years into the future. Thus, it might well be that 20 years from now students will be buying microcomputers that rival today's multimillion-dollar supercomputers.

Along with substantial improvements in computer speed, the past 50 years have seen substantial improvements in computer memory, secondary storage devices, and in telecommunication systems. Price to performance ratios have improved by factors of more than a million.

Here is a specific example. Microcomputers came into widespread use in the late 1970s and early 1980s. In those days, a 5-megabyte hard disk drive for a microcomputer cost about $5,000. This is $1,000 per megabyte, or $1,000,000 per gigabyte. Now, the cost of a hard drive is less than 50-cents per gigabyte.

Here are two more specific examples. The Russian satellite Sputnik was launched into orbit in 1957. Now, dish TV and satellite-based Global Positioning Systems (GPS) are routine consumer products. The first commercial installation of fiber-optic cables for telecommunication was in 1977. Now, one fiber-optic cable can carry hundreds of thousands of phone conversations, and cables are typically installed in bundles of many cables.

Many areas of research and development depend upon ICT. In some sense, the greater the ICT dependence, the greater the rate of progress. The human genome project provides a good example of a speed up in technological progress. The project that began in 1990 and ended in 2003 cost about $300 million. Initial progress on the project was very slow. Progress speeded up considerably as the project proceeded, and most of the sequencing was complete in the last couple of years.

In 2005, the cost of sequencing a person's genome was estimated to be about $2.2 million, and various organizations and people believe that the cost may eventually be as low as $1,000 (Wade, 2006).

These massive changes in ICT-related capabilities and price to performance ratios are major change agents. From your personal point of view, perhaps the major challenges are accommodating appropriate aspects of these changes into your everyday live, and getting an education that helps prepare you for the continuing high rate of change in ICT.

Forecasting the Future

A very short description of science is, "Science is description and prediction." Scientists have made good progress in describing our solar system and predicting where the moons, planets, and various comets will be many years in the future. Scientists have an increasingly good understanding of astronomy, biology, chemistry, geology, physics, and many other areas of science.

However, there are many areas of scientific research where it is difficult—if not downright impossible—to make accurate long range forecasts. For example, weather forecasters regularly provide weather forecasts for the next day, week, or month. The longer into the future these forecasts go, the less accurate they become. Forecasts of earthquakes and volcanic eruptions are not very accurate.

Now, consider forecasting in areas such as the stock market, consumer purchases, and other human activity areas. While forecasters in these areas often make use of scientific methods and computers, they lack the underlying theories that make possible the accurate predictions of the sciences. Will consumers like and buy a proposed new product or service? Will a movie or TV series that is being planned attract a large audience? Will a racehorse stumble and break a leg?

Where does this leave you, as you plan for and work to achieve your higher education aspirations? What might the future look like? How can you plan for a future world that might be a lot different than our current world?

Well… I can give some advice, but I cannot guarantee it will work for you. Here is the way I see it:

1. Plan for a future world in which there will be an increasing number of people. Work to improve your people skills and to improve your ability to function in a world being made "smaller" by steady improvements in transportation, communication, and worldwide competition for jobs.

2. Plan for a world that faces a steadily increasing pressure on the world's resources, worldwide competition for these resources, and a steadily increasing challenge of sustainability. Global warming is a massive challenge.

3. Plan for a world in which there will be a still faster pace of change in science and technology. How will you deal with progress in genetics (gene therapy, cloning, designer babies), drugs to enhance mind and body, and entertainment that is steadily growing in its attention grabbing and attention holding capabilities?

4. Plan for a world in which you will need to be a lifelong learner and will need to make many changes to accommodate large changes going on in the world. Assume that computers will get steadily "smarter" and that computerized equipment will get steadily more capable. You will need

to deal with these types of changes in your work, family and personal life, and leisure.

A good starting point is to increase your understanding of the current situation and near term future situation in various rapidly changing areas of science and technology. An easy way to do this is to spend some time viewing some of the free videos that are available on the Web. Examples are given in the next section.

Some Visionaries

ICT and the underlying discipline of computer and information are large and steadily growing. One way to gain some insight into the future of these areas is to study some of the work of leading researchers and practitioners. Learn about a few of the movers and shakers. Pay attention when you hear there names in the news or see articles written about them. I find it particularly interesting and useful to read some of the talks and view some of the videos of these leaders.

This section provides brief introductions to a few of the people who are creating the future of ICT. These people are sufficiently visionary that one doesn't need to study their most recent publications to gain useful insight into where they think the world is heading. Indeed, I find it is fun to read some of their older work and see how well they have predicted the future.

You are undoubtedly familiar with Bill Gates (Microsoft) and Steve Jobs (Apple) and the ongoing contributions they and their companies are making to the ICT world. There are many other entrepreneurs and visionaries who are changing our world. *The 50 Most Important People on the Web* (Null, 2007) contains brief discussions about many of these people. You might want to build an island of expertise based upon knowing about some of these people. The following sections focus on people that I consider especially noteworthy.

Ray Kurzweil: The Singularity is Near

Ray Kurzweil is a prominent computer-oriented futurist. He did his doctoral work in Artificial Intelligence under the supervision of Marvin Minsky, who is one of the pioneers of this field. He was awarded the National Medal of Technology by President Clinton and has received a number of other high level awards. He is an entrepreneur who has started a number of high tech companies (Kurzweil Technologies, n.d.).

Kurzweil's book: *The Singularity is Near: When Humans Transcend Biology* contains a number of forecasts, with a special emphasis on genetics, nanotechnology, and robotics. The *singularity* referred to in the title of his book is a time when computer intelligence exceeds human intelligence.

Quoting from his book (Kurzweil, 2005, page 136):

> I set the date for the Singularity—representing a profound and disruptive transformation is human capability—as 2045. *The nonbiological intelligence created in that year will be one billion times more powerful than all human intelligence today.* [Italics added for emphasis]

Before you dismiss such a wild-eyed forecast out of hand, examine Kurzweil's credentials and his record of success as a far out thinker and forecaster. Quoting from (Kurzweil Technologies, n.d.):

> Ray Kurzweil was inducted in 2002 into the National Inventors Hall of Fame, established by the U.S. Patent Office. He received the $500,000 Lemelson-MIT Prize, the nation's largest award in

invention and innovation. He also received the 1999 National Medal of Technology, the nation's highest honor in technology, from President Clinton in a White House ceremony. He has also received scores of other national and international awards, including the 1994 Dickson Prize (Carnegie Mellon University's top science prize), Engineer of the Year from Design News, Inventor of the Year from MIT, and the Grace Murray Hopper Award from the Association for Computing Machinery. He has received twelve honorary Doctorates and honors from three U.S. presidents.

Now that you are suitably impressed by some of his credentials, you might want to:

- Learn more about Kurzweil and his work by viewing the 25-minute video of when he was awarded the year 2001 seventh annual $500,000 Lemelson prize. See: http://www.lemelson.org/innovation/3ivision.php.

- See Kurzweil's optimistic views of our future. For a 24 minute video of a talk given in 2005, see http://ted.com/tedtalks/tedtalksplayer.cfm?key=r_kurzweil.

- Learn more information about Kurzweil and artificial intelligence, see KurzweilAI.net at http://www.kurzweilai.net/. If "far out" thinking about the future interests you, this is a great site to explore. For example, at http://www.kurzweilai.net/meme/frame.html?main=memelist.html?m=4%23688 you can read a transcript of a November 30, 2006 debate on machine consciousness.

After you have viewed one of more of the videos listed above, spend some time thinking about how Kurzweil's vision of the future of technology fits in with your forecasts of the future you are preparing for through your higher education. There is no guarantee that Kurzweil's forecasts will prove to be accurate. While many people agree with his thinking, many others strongly disagree. My personal opinion is that you and other students should be preparing yourself for life in a world where many of Kurzweil's forecasts have proven to be relatively accurate.

Thomas Friedman: The World is Flat

Thomas Friedman is a three-time winner of the Pulitzer Prize. His 2005 book, *The World is Flat: A Brief History of the Twenty-First Century*, captures many of the key ideas of change going on throughout the world due to ICT, improvements in transportation, and improvements in education. Friedman's use of the term *flat* is intended to convey the idea of a level playing field in the worldwide production and sale of goods and services (Friedman, 2005).

One example of this flatness is the cost of long distance phone calls. If you and the person you want to talk to can connect on the Internet, you can carry on a "free" phone conversation via the Internet. That is, the only cost is whatever you are paying already to have the Internet connectivity. Indeed, if you both have appropriate video cameras such as those now often build into computers or that can be purchased at a modest cost, you can carry on videophone conversations.

A Google search of *Thomas Friedman video* will provide you with access to a number of his talks and interviews. Many of these are more than an hour in length—he has a lot to say! Here are two recommendations:

- *Doing Business in a Flat World: Globalization, Entrepreneurship, Micro-Economic Reform,* a presentation on the factors that have contributed to the increasing

connectedness—or "flattening"—of the world. A 1.5 hour presentation is available at http://info.worldbank.org/etools/Bspan/PresentationView.asp?PID=1507&EID=732.

- Learn more about Friedman and access some of his writings at http://www.thomaslfriedman.com/.

As you think about and plan for your future, remember the tune "It's a small world" and pay attention to Friedman's insights that the world is getting smaller. Work to become a citizen of the world who functions well in a rapidly changing world that is growing smaller and flatter.

Nicholas Negroponte: The *One Laptop Per Child* Project

ICT is a worldwide reality. However, it is more of a reality in some parts of the world than in others. Nicholas Negroponte is former Director of the MIT Media Lab, one of the world's leading ICT-based, education-oriented, research and development centers. Quoting from the Wikipedia:

> The MIT Media Lab in the School of Architecture and Planning at the Massachusetts Institute of Technology engages in education and research in the digital technology used for expression and communication. It was founded in 1985 by MIT Professor Nicholas Negroponte and former MIT President Jerome Wiesner (now deceased).

Negroponte is dyslexic, which makes reading and writing more of a challenge than it is for non-dyslexic people. His 1995 book *Being Digital* presents a clear picture of similarities and differences of being in the business of moving bits (of information) versus moving physical (solid objects) made up of atoms (Negroponte, 1995). Quoting from this book:

> 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.
>
> …
>
> 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.

Thus, for example, an electronic copy of a book can be in a repository, and electronic copies can be quickly distributed around that world at a very low cost. The same situation holds for distributing music.

Negroponte is playing the lead role in an effort to bring inexpensive networked computers to the world. The *One Laptop Per Child* project is dedicated to making a networked $100 laptop a reality. The designers of the machine realize that many of the people they want to reach do not have electrical power. The machines consume so little power that they can be human powered (think in terms of a wind up flashlight).

Mass production of these computers began in the first quarter of 2007, with the expectation of first deliveries to begin in the summer of 2007. The first machines are being sold in large lots (think of selling a million computers at a time to a government) with about seven different countries interested in making the initial purchases. Initially, the machines will cost in the range of about $160 to $175, but the expectation is that eventually they will cost under $100.

Nicholas Negroponte has committed himself to spending the rest of his professional career spearheading this project. His sincerity and devotion to the project are evident in the materials listed below.

- February 2006 19-minute video available at http://tedblog.typepad.com/tedblog/2006/08/nicholas_negrop.html. This video estimated sales of 7 to 10 million laptops in 2007, and sale of 100 to 200 million in 2008. The distribution design is that the computers will be sold in very large lots to government that will then distribute them free to children.

- Technical specifications and other information about the laptop available at http://www.laptop.org/.

- Parts of his 1995 book *Being Digital* as well as a number of his articles are available at http://archives.obs-us.com/obs/english/books/nn/bdcont.htm.

Neil Gershenfeld: MIT Center for Bits and Bytes

Neil Gershenfeld is a professor at MIT and director of the Center for Bits and Atoms. One of the projects of this is called the Fab Lab. The goal is to develop a moderately priced set of equipment that can be used to invent and fabricate devices. The current $20,000 form of the Fab Lab is being used for educational purposes at a variety of sites throughout the world. His 18 minute video at http://www.ted.com/tedtalks/tedtalksplayer.cfm?key=n_gershenfeld is provocative and far reaching. It provides insights into "what comes next?"

Malcolm Gladwell: The Tipping Point

Malcolm Gladwell is the author of *The Tipping Point* (2000) and Blink (2006). *The Tipping Point* explores change and the idea that major changes can occur relatively quickly. The idea of a tipping point is roughly like the idea of when a teeter-totter suddenly tips from one side to the other as one adds more weight to the end that is up in the air.

Quoting from Gladwell (n.d.):

> One of the things I'd like to do is to show people how to start "positive" epidemics of their own. The virtue of an epidemic, after all, is that just a little input is enough to get it started, and it can spread very, very quickly. That makes it something of obvious and enormous interest to everyone from educators trying to reach students, to businesses trying to spread the word about their product, or for that matter to anyone who's trying to create a change with limited resources.
>
> …
>
> Beyond that, I think that *The Tipping Point* is a way of making sense of the world, because I'm not sure that the world always makes as much sense to us as we would hope. I spent a great deal of time in the book talking about the way our minds work—and the peculiar and sometimes problematic ways in which our brains process information. Our intuitions, as humans, aren't always very good. Changes that happen really suddenly, on the strength of the most minor of input, can be deeply confusing. People who understand *The Tipping Point,* I think, have a way of decoding the world around them.

How does this apply to you? Are you able and willing to make significant changes in yourself and in what you are doing? Alternatively, are you so pleased with yourself that you cannot see any need for change? After all, change is difficult and you might make a change that is for the worse, rather than for the better.

Here are some sources of information about Malcolm Gladwell's work:

- The Website http://www.gladwell.com/tippingpoint/index.html is a short document covering some of the key ideas in *The Tipping Point*.

- The Website http://www.itconversations.com/shows/detail478.html contains the audio of a talk that Gladwell gave focusing on ideas in his book, *Blink*. This book provides an analysis of decision-making and how people tend to make very quick decisions that are often wrong. You might want to skip over the first few minutes of this audio, as it consists of a long introduction that has little relevance to the presentation.

- The 18 minute video at http://video.google.com/videoplay?docid=-6449479356304659254 provides insight into significant changes in product development research and the idea that "one size fits all" is not a good approach to product development and building sales.

The idea of one-size fits all versus individualization is also important in your education. Nowadays, it is common to order a car or a computer, specify a number of the features that you want it to have, and the manufacturer will build the precise car or computer you specify. That is, within limits, the car and computer manufacturers have learned to mass-produce to meet individual differences.

Most institutions of higher education have a function somewhere in the middle of one size fits all versus a high level of individualization. If you are in the process of selecting a school or a program of study, you might want to think about the level of individualization that will be available to you. If you are already in a program of study, think about what you can do to shape the program to better fit your personal needs. Rather than be a passive acceptor of what the school and program offers, put some effort into shaping and inventing your personal future.

Technology, Entertainment, Design (TED)

TED started out in 1984 as conference bringing together people from the worlds of technology, entertainment, and design. Over the years, it has broadened its scope. Recently, it has received outside funding to make videos of the conference talks and post them to the Web.

Most of the videos are about 20 to 25 minutes in length. They are presentations by many of the movers and shakers of the world. If you want to know where we are now and where we are going, spend some time viewing and listening to the visionaries. See http://www.ted.com/.

I strongly recommend viewing a variety of these videos. Learn about state of the art activities in technology, entertainment, design, business, science, culture, arts, and global issues. While I was writing this book, the topic *How the Mind Works* was featured on the homepage of the Website. Surely, you want to know more about recent advances in brain science and how minds work.

Here is another TED example. Quoting from: http://www.ted.com/tedtalks/tedtalksplayer.cfm?key=h_fisher: "Helen Fisher is an anthropologist with Rutgers University, specializing in gender differences and the evolution of human emotions. Her most recent book is *Why We Love: The Nature and Chemistry of Romantic Love*. In this wide-ranging talk, she outlines the bio-chemical foundations of love (and lust), and discusses the natural talents of women, and their new significance in the modern world. (Recorded February 2006 in Monterey, CA. Duration: 24:13)"

ICT is Worldwide

Many people who live in the United States assume that the U.S. is the world leader in all aspects of the development and use of ICT. Thus, they are surprised when presented with facts such as:

- Japan is by far the world leader in fiber optic connectivity into people's homes See the April 4, 2007 video at http://www.itif.org/index.php?id=38,

- The United States is now ranked 15th among 30 industrialized nations in terms of broadband connectivity. See http://www.oecd.org/document/7/0,2340,en_2649_34223_38446855_1_1_1_1,00.html.

- The Wikipedia (a free encyclopedia written by volunteers) is actually more than 250 different Wikipedias, each in a different language. Fifteen of these Wikipedias each contain more than a hundred thousand articles. See http://meta.wikimedia.org/wiki/List_of_Wikipedias.

- The Web was "invented" by Tim Berners-Lee. Born and educated in England, he developed the Web while working for CERN, the European Particle Physics Laboratory in Geneva, Switzerland. Access a short video of Berners-Lee talking about Internet Neutrality at http://people.w3.org/~djweitzner/blog/?p=74. (The Website may download the video to your desktop, in which case you will need to click on the file to run the video.)

- In the 2007 Association for Computing Machinery world computer programming contest, the only U.S. university to finish in the top 10 was MIT, which placed 4th. See http://icpc.baylor.edu/icpc/.

Summary and Self-Assessment

Improvements in transportation, communication, and freely sharing (or sale) of intellectual property make the world smaller and flatter. This means that you need to think about the extent to which you want to become a citizen of the world, functioning well in different countries and cultures. It also means that you need to think about gaining levels of expertise that will serve you well in your economic, social, cultural, and other aspects of your life.

One key to gaining increased levels of expertise is to clearly identify areas in which you want to increase your expertise, find or develop measures of your current levels of expertise, and consciously work toward achieving the higher levels of expertise that you want to achieve.

The idea of islands of expertise may prove quite useful to you. Even when you were in grade school, you and/or some of your fellow students may well have known more about dinosaurs or super heroes than your teachers. It is easy to select a narrow area and develop a level of expertise that is above that of your peers and your teachers.

The $100 laptop project is a great area in which to develop an island of expertise. In recent years, there has been a huge surge in worldwide connectivity via cell phones. A cell phone can be used to connect to the Internet (for example, to do email) and the Web (for example, to retrieve information), but the human-machine interface of a cell phone is not nearly as convenient as can be provided by a somewhat larger machine, such as a laptop. How will the world change as many hundreds of million of people throughout the world acquire access to the

Internet and Web. How will our educational systems, businesses, family life, social life, and so on be affected by continued rapid improvements in connectivity?

Think about the discipline or disciplines you are specializing in during your college work. How will they be affected by continuing rapid progress in the cost effectiveness of ICT systems? You may well be able to use this thinking as a starting point for developing islands of expertise that will help to differentiate you from your fellow students and from people who are already have well established careers in the disciplines.

Chapter 3

Expertise and Problem Solving

"Through learning we re-create ourselves. Through learning we become able to do something we never were able to do. Through learning we re-perceive the world and our relationship to it. Through learning we extend our capacity to create, to be part of the generative process of life. There is within each of us a deep hunger for this type of learning." (Peter Senge, 1990)

The history of formal schooling designed to teach reading, writing, and arithmetic goes back more than 5,000 years, to the time of the invention of writing. The 3Rs are mind tools—aids to the human brain. It takes considerable time and effort to develop a level of expertise in these disciplines that meets contemporary standards.

Your current level of expertise in these areas is useful to you in your everyday life and in your academic pursuits. You routinely use this expertise in representing and solving problems that you encounter in your everyday life.

Problem solving is part of every discipline, and it is a discipline of study in its own right. Computers are a powerful aid to solving problems in every academic discipline. This chapter includes an introduction to roles of ICT in problem solving.

There is a field of study called the Scholarship of Teaching and Learning, or the Science of Teaching and Learning (SoTL). This discipline contains considerable information that is useful both to students and to teachers. Since you routinely help yourself and others to learn, SoTL is doubly useful to you.

Expertise

Figure 3-1 is a general-purpose expertise scale. At the left end of the scale, a person's knowledge and skills in an area may be so limited that some unlearning needs to occur to move up the scale. For example, this situation exists in some parts of science and medicine, where a person's initial learning is wrong and does not serve as a useful foundation for future learning.

General-Purpose Expertise Scale for a Discipline

1	2	3	4	5	
Less than a useful level of knowledge and skill.	Level to meets one's personal needs.	Level to meets an employer's needs.	Relatively fluent, broad-based and higher-order knowledge and skills.	Professional level of knowledge and skills.	World class

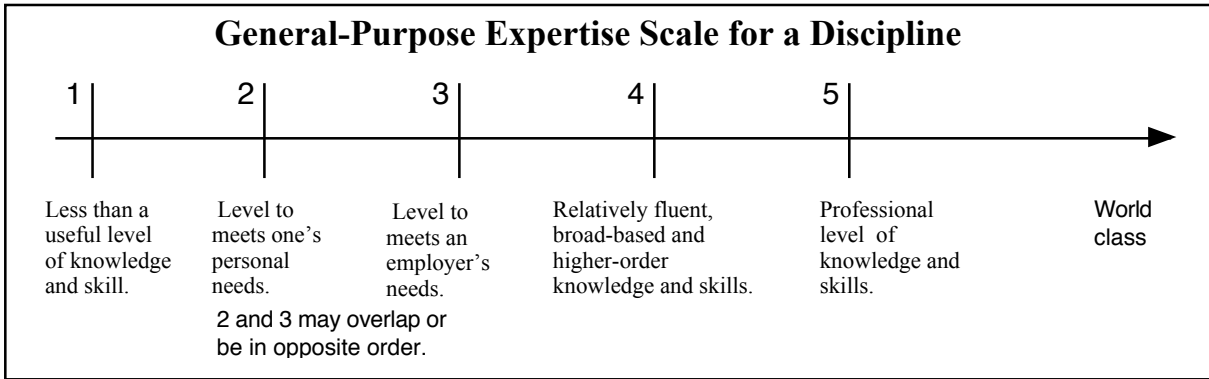2 and 3 may overlap or be in opposite order.

Figure 3-1. General-purpose expertise scale.

Consider a limited subdiscipline you have not previously encountered. Then think about the level of expertise you might achieve in this subdiscipline in 1 hour, 10 hours, 100 hours, 1,000 hours, and 10,000 hours of study and practice. (See Figure 3-2.) The level of expertise you will achieve depends on a number of things, such as your current level of expertise in closely related areas, your innate ability in the area, the quality of instruction and coaching you receive, and your dedication and perseverance. This simple set of observations lies at the very heart of education. A well-designed and well-implemented educational system helps students gain expertise faster than they would gain it without any outside help.

1 hour	10 hours	100 hours	1,000 hours	10,000 hours	100,000 hours

Develop an island of expertise

Develop a very high level of expertise
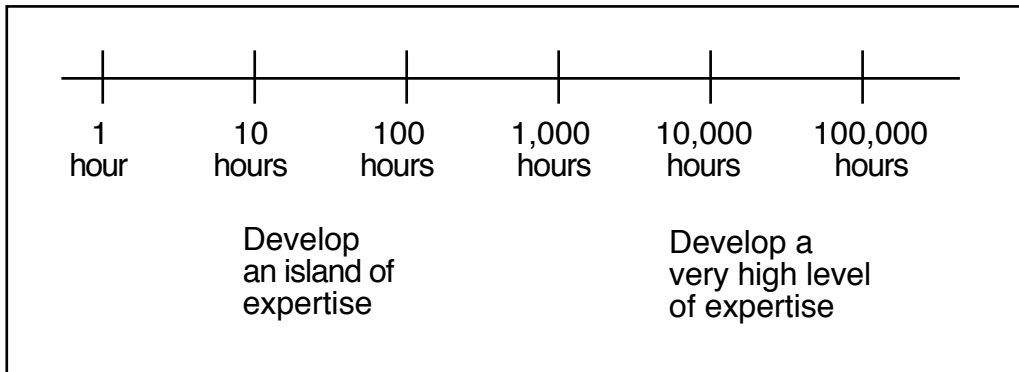
Figure 3-2. Time to develop expertise.

"Be all you can be" lies in the 10,000 to 100,000 hours range, combined with 10 years or more of concerted and guided effort. The level you reach depends on many things, such as quality of instruction and coaching, natural abilities, intrinsic motivation and drive, and extrinsic motivation. However, you can develop an island of expertise (a narrow pocket of expertise) in much less time and with much less effort.

In gaining an increased level of expertise in any area, both nature and nurture are important. It is not clear whether the extent to which your final level of expertise in an area depends more strongly on your innate abilities (nature, genetic disposition) or on the nurture you receive (Ericsson, n.d.). Moreover, there is the issue of intrinsic motivation and drive versus extrinsic motivation, or being coerced to do the studying and practice. The following quote from Jonah Lehrer (2006) helps capture the basic elements of nature-versus-nurture arguments:

Two obvious rebuttals to the argument that talent is just a matter of learning by doing are Mozart and Tiger Woods. Mozart famously began composing symphonies as an eight-year-old, and Woods was the world's best golfer at 21. But do they really contradict the "learning by doing" principle?

Not so much. Mozart began playing at two, and if he averaged 35 hours of practice a week—his father was known as a stern taskmaster—he would, by the age of eight, have accumulated Ericsson's golden number of 10,000 hours of practice. In addition, Mozart's early symphonies are not nearly as accomplished as his later works.

Lehrer goes on to say:

Thanks to an encouraging father who happened to be a golf fanatic, Tiger [Woods] took his first golf swing before he took his first steps. When he was 18 months old, his dad started taking him to the driving range. By the age of three, Tiger was better than most weekend amateurs.

This allowed Woods to get a head start on his current competitors, but what really made him great is how he practices. For starters, his routine is merciless. Rain or shine, Woods sets out. More importantly, he always makes sure his practice sessions revolve around learning by doing. He analyzes sequential snapshots of himself playing, relentlessly scrutinizes the elements of his swing, then drills these subtle alterations into his nervous system through thousands of repetitions. Of course, more practice leads to more new ideas, which leads to more practice.

The quantity 10,000 hours is frequently mentioned as the amount of time it takes to achieve one's potential or come close to achieving one's potential. (The figure 10 years is also often used as an estimate, instead of 10,000 hours.) Thus, for example, suppose you have never played a game of chess. In 1 hour, you can learn the rudiments of what constitutes a legal move and what constitutes winning a game. In 10,000 hours, you will have made considerable progress toward being as good as you can be.

In chess, however, additional hours of study and practice will likely continue to move you up the expertise scale. For example, the current average age of the world's top-ranked human chess players is about 30. These people have put in 30,000 to 40,000 hours or more in gaining their current level of chess expertise.

While there are some young prodigies in music performance, world-class instrumentalists typically have put in 20,000 to 30,000 hours to achieve their current level of expertise.

High Level of Expertise in an Academic Discipline

Consider a faculty member with a doctorate who has just been promoted to an associate professorship in a research university. This person has probably put in well over 20,000 hours to achieve his or her current level of discipline-specific expertise. Most of these hours of time were spent during upper division undergraduate specialization, four to six years of graduate school, and five to six years serving as an assistant professor.

This figure of more than 20,000 hours can be contrasted with the time invested by a student before beginning serious work in a college major. For example, consider a student who begins to receive some formal instruction in math while in kindergarten, and then takes math every year up through his or her freshman year in college. I would estimate that this student has invested about 2,000 hours of time at school and home in developing the level of expertise that he or she has attained.

Research on Expertise

There has been substantial research on expertise and gaining expertise in various disciplines. Some of this is summarized in Ericsson (n.d.), who discusses ideas highly relevant to higher education in any discipline:

> *The difference between experts and less skilled subjects is not merely a matter of the amount and complexity of the accumulated knowledge; it also reflects qualitative differences in the organization of knowledge and its representation* (Chi, Glaser & Rees, 1982). Experts' knowledge is encoded around key domain-related concepts and solution procedures that allow rapid and reliable retrieval whenever stored information is relevant. Less skilled subjects' knowledge, in contrast, is encoded using everyday concepts that make the retrieval of even their limited relevant knowledge difficult and unreliable. Furthermore, experts have acquired domain-specific memory skills that allow them to rely on long-term memory (Long-Term Working Memory, Ericsson & Kintsch, 1995) to dramatically expand the amount of information that can be kept accessible during planning and during reasoning about alternative courses of action. The superior quality of the experts' mental representations allow them to adapt rapidly to changing circumstances and anticipate future events in advance. *The same acquired representations appear to be essential for experts' ability to monitor and evaluate their own performance (Ericsson, 1996; Glaser, 1996) so they can keep improving their own performance by designing their own training and assimilating new knowledge.* [Italics added for emphasis]

The quoted paragraph is a good example scholarly writing that is dense with important ideas. One of the key ideas is that experts learn how to learn in their area of expertise, and they learn how to self-assess. This suggests that we might want to place more emphasis on these two general ideas in all of our teaching.

A nice summary of some of the research on expertise—with a special emphasis on research on chess experts—is available in Phillip Ross's (2006) work. In talking about long-term working memory, Ross says:

> The one thing that all expertise theorists agree on is that it takes enormous effort to build these structures in the mind. Simon coined a psychological law of his own, the 10-year rule, which states that it takes approximately a decade of heavy labor to master any field. Even child prodigies, such as Gauss in mathematics, Mozart in music and Bobby Fischer in chess, must have made an equivalent effort, perhaps by starting earlier and working harder than others.
>
> …
>
> *Ericsson argues that what matters is not experience per se but "effortful study," which entails continually tackling challenges that lie just beyond one's competence. That is why it is possible for enthusiasts to spend tens of thousands of hours playing chess or golf or a musical instrument without ever advancing beyond the amateur level and why a properly trained student can overtake them in a relatively short time.* [Italics added for emphasis]

I find the educational implications of these statements quite interesting. Experts in a discipline have learned to do the *effortful study* that advances expertise, and they put in the thousands of hours of effort needed to move to a high level of expertise. A good teacher or a good coach helps students learn to do this type of effortful study.

Ross also gives a brief summary of studies that attempt to get at the issue of nature versus nurture in achieving a high level of expertise. He concludes that, "the preponderance of psychological evidence indicates that experts are made, not born. What is more, the demonstrated ability to turn a child quickly into an expert—in chess, music and a host of other subjects—sets a clear challenge before the schools."

Problem Solving

In discussing problem solving situations, I include the following:

- Question situations: recognizing, posing, clarifying, and answering questions.

- Problem situations: recognizing, posing, clarifying, and then solving problems.

- Task situations: recognizing, posing, clarifying, and accomplishing tasks.

- Decision situations: recognizing, posing, clarifying, and making good decisions.

- All situations: using higher-order critical, creative, wise, and foresightful thinking to do all of the above. Often the results are shared, demonstrated, or used as a product, performance, or presentation.

You have been solving problems and accomplishing tasks all of your life. My goal here is to broaden your internal model of the terms problem and problem solving. I want you to have a mental model that fits with developing a high level of expertise in any discipline you decide to study in depth.

It may surprise you that the list places so much emphasis on posing questions, problems, and tasks. Gaining skill in such posing is an important part of increasing expertise in a discipline. Think about this when you are taking a course. From time to time as you listen to a lecture or participate in a discussion, think about what deep, penetrating questions you might raise and/or that you are learning to answer.

Here is a definition of *problem* that I have found useful in my teaching and writing:

You (personally) have a problem if the following four conditions are satisfied:

1. You have a clearly defined given initial situation.

2. You have a clearly defined goal (a desired end situation). Some writers talk about having multiple goals in a problem. However, such a multiple goal situation can be broken down into a number of single-goal problems.

3. You have a clearly defined set of resources that may be applicable in helping you move from the given initial situation to the desired goal situation. These typically include some of your time, knowledge, and skills. Resources might include money, the Web, and the telecommunication system. There may be specified limitations on resources, such as rules, regulations, guidelines, and timelines for what you are allowed to do in attempting to solve a particular problem.

4. You have some ownership—you are committed to using some of your own resources, such as your knowledge, skills, time, and energy, to achieve the desired final goal.

In many problem-solving situations, ICT and computerized tools are resources of the type mentioned in the third part of the definition. These resources have grown more powerful over the years. That is one reason why it is so important to integrate the use of computers in problem solving thoroughly into the basic fabric of the courses you are taking and the areas you are studying.

The fourth part of the definition of a problem is particularly important. Unless you have ownership—through an appropriate combination of intrinsic and extrinsic motivation—you do not have a problem. Motivation, especially intrinsic motivation, is a huge topic in its own right, and I will not attempt to explore it in detail in this book. Edward Vockell (n.d) maintains an online book*, Educational Psychology: A Practical Workbook*. The fifth chapter provides a nice discussion of motivation.

George Polya

George Polya was one of the leading mathematicians of the 20th century, and he wrote extensively about problem solving. His 1945 book, *How to Solve It: A New Aspect of Mathematical Method,* is well known in math education circles (Polya, 1957).

In a talk to elementary school teachers, Polya said:

> To understand mathematics means to be able to do mathematics. And what does it mean doing mathematics? In the first place it means to be able to solve mathematical problems. For the higher aims about which I am now talking are some general tactics of problems—to have the right attitude for problems and to be able to attack all kinds of problems, not only very simple problems, which can be solved with the skills of the primary school, but more complicated problems of engineering, physics and so on, which will be further developed in the high school. *But the foundations should be started in the primary school. And so I think an essential point in the primary school is to introduce the children to the tactics of problem solving. Not to solve this or that kind of problem, not to make just long divisions or some such thing, but to develop a general attitude for the solution of problems.* **(**Polya, 1969) [Italics added for emphasis]

Polya's statements about mathematics apply to any academic discipline. A student who takes one or more college courses in a discipline should gain an understanding of the general nature of the types of problems it addresses. The student should make some progress in thinking like an expert in the discipline.

Polya (1957) provides a general heuristic strategy for attempting to solve any math problem. I have reworded his strategy so that it is applicable to a wide range of problems in a wide range of disciplines—not just in math. This six-step strategy can be called the Polya Strategy or the Six Step Strategy.

It is a heuristic strategy. There is no guarantee that use of the Six Step Strategy will lead to success in solving a particular problem. You may lack the knowledge, skills, time, and other resources needed to solve a particular problem, or the problem might not be solvable.

1. Understand the problem. Among other things, this includes working toward having a well-defined (clearly defined) problem. You need an initial understanding of the Givens, Resources, and Goal. This requires knowledge of the domain(s) of the problem, which could well be interdisciplinary. You need to make a personal commitment—have ownership—to solving the problem.

2. Determine a plan of action. This is a thinking activity. What strategies will you apply? What resources will you use, how will you use them, in what order will you use them? Are the resources adequate to the task? On hard problems, it is often difficult to develop a plan of action. Research into this situation suggests that many good problem solvers "sleep on the problem." That is, after working on a problem for quite a while with little or no success, they put the problem out of their minds and do something else for days or even weeks. What may well happen

is that at subconscious level the mind continues to work on the problem. Eventually, an "ah-ha" experience sometimes occurs.

3. Think carefully about possible consequences of carrying out your plan of action. Focus major emphasis on trying to anticipate undesirable outcomes. What new problems will be created? You may decide to stop working on the problem or return to step 1 because of this thinking.

4. Carry out your plan of action. Make appropriate use of physical and cognitive tools in this activity. Do reflective thinking as you carry out your plan. This thinking may lead you to the conclusion that you need to return to one of the earlier steps. Note also that this reflective thinking contributes to increased expertise.

5. Analyze the results achieved by carrying out your plan of action. Then do one of the following:

    A. If the problem has been solved, go to step 6.

    B. If the problem has not been solved and you are willing to devote more time and energy to it, make use of the knowledge and experience you have gained as you return to step 1 or step 2.

    C. Make a decision to stop working on the problem. This might be a temporary or a permanent decision. Keep in mind that the problem you are working on may not be solvable, or it may be beyond your current capabilities and resources.

6. Do a reflective analysis of the steps you have carried out and the results you have achieved to see if you have created new, additional problems that need to be addressed. Reflect on (do metacognition on) what you have learned by solving the problem. Think about how your increased knowledge and skills can be used in other problem-solving situations. Work to increase your reflective intelligence!

Many of the steps in this Six Step Strategy require careful thinking. However, there are a steadily growing number of situations in which much of the work of Step 4 can be carried out by a computer. The person who is skilled at using a computer for this purpose may gain a significant advantage in problem solving over a person who lacks computer knowledge and skill. This type of knowledge and skill in using computers is a way to build on the previous work of others.

Step 6 emphasizes metacognition. There is considerable research to support the contention that metacognition is a key to building expertise and getting better at problem solving. It is a process in which you think about what you already know and how what you are doing ties in with what you already know.

Every problem-solving activity that you do during your everyday life provides an opportunity for metacognition.

• You make a decision. How and why did you make that decision? How do you know it is a good decision?

• You pose a question. What led you to pose this particular question? In the process of thinking about the question, did you also posit the answer you expect to get or find?

Did you think about the usefulness of possible answers? Was the question carefully constructed so that an answer can be found and will prove useful?

* You solved a relatively challenging problem. What knowledge and skills did you draw on? What did you learn during the problem solving process that will likely be useful when you encounter other somewhat similar problems in the future?

Building on Previous Work

One of the most important ideas in problem solving is to build on your own previous work and on the previous work of others. That is, one way to solve a problem is to retrieve from your own memory either a solution to the problem or a method for solving the problem. Another way is to retrieve this information from another person, from a physical library, or from a virtual library such as the Web.

The human race's accumulated knowledge is stored in tens of millions of books, monographs, journals, Web publications, and other forms of publication written in many different languages. Much of the accumulated knowledge in a discipline is only accessible to those who have studied the discipline at a graduate school level. While it is easy to talk about the importance of building on the knowledge of others, it can take many years of hard work to develop the knowledge needed to read and understand the accumulated research knowledge in a discipline.

Moreover, most of the accumulated knowledge in any specific academic discipline is not readily available or easily retrievable. It is scattered throughout the libraries of the world, it is written in many different languages, and much is stored in people's heads. Over time, such difficulties of accessing materials will decrease as the materials are digitized and become accessible through the Web. Progress in the computer translation of languages will help, as will the development of better expert systems (a type of Artificially Intelligent computer system that has a relatively high level of expertise in a narrow field).

Perhaps you don't know much about expert systems. This topic is covered in Chapter 4. For now, it suffices for you to know that thousands of artificially intelligent expert systems are in use. Each has a very narrow range of capability. For example, nowadays if you apply for a loan at a bank, the decision as to whether to grant you the loan will likely be made mainly by a computer system. Because of progress in this small area, there are far fewer human loan officers working in banks.

To summarize, one goal in the study of an academic discipline should be to learn to access the accumulated, discipline-specific knowledge that is appropriate to their educational level and needs and to learn to use this accumulated knowledge to solve problems and accomplish tasks. Certainly you will want to learn what aspects of jobs in your chosen area of study are likely to change significantly or even disappear because of the increasing capability of computer systems.

To Memorize or Not to Memorize: That Is the Question

Researchers in the area of expertise distinguish between rote memory (which involves little understanding) and the type of memorization being done by experts in a discipline. Rote memory is useful in problem solving. However, a focus on rote memory tends to be a poor approach to building a useful level of expertise in any discipline.

As Ericsson (n.d., in press) notes:

The primary goal for all experts is to excel at the representative tasks in their domains. For example, chess experts need to find the best moves to win chess matches and medical experts have to diagnose sick patients in order to give them the best treatment. … As part of performing the representative task of selecting the best move, the experts encode the important features of the presented information and store them in accessible form in memory. *In contrast, when subjects, after training based on mnemonics and knowledge unrelated to chess, attain a recall performance comparable with that of the chess experts, they still lack the ability to extract the information important for selecting the best move.* [Italics added for emphasis]

The ideas in Ericsson's quote have deep educational implications. Many students resort to rote memory with only modest understanding in order to pass tests and the course. The long-term retention of such memorized information tends to be quite low and this approach to learning does not contribute much to building a useful level of expertise.

Academic Disciplines

The terms *discipline* and *academic discipline* have been used repeatedly in earlier parts of this book. I did not define the terms, since I am sure that you already know what I am talking about.

However, in this section I wan us to take a deeper look into academic disciplines. I use the term *discipline* when I am talking about a large and inclusive discipline of study, a sub discipline, an interdisciplinary discipline, and so on. Each academic discipline or area of study can be defined by a combination of general things such as:

- 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, and language, including notation and special vocabulary.

- Its methods of teaching, learning, assessment, and thinking. What it does to preserve and sustain its work and pass it on to future generations.

- 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 and distinguish among: a) a novice; b) a person who has a personally useful level of competence; c) a reasonably competent person, employable in the discipline; d) an expert; and e) a world-class expert.

Notice the emphasis on solving problems, accomplishing tasks, producing products, doing performances, accumulating knowledge and skills, and sharing knowledge and skills. Suppose that you are taking a course in which the book you are currently reading is part of the required readings. You are browsing along, perhaps even enjoying the reading, and you come to a list such as the one given above.

"Hmm," you think. "What should I do now? I wonder if the teacher expects me to memorize this bulleted list. What are the chances it will be on a test? Maybe all I need to do is understand the general idea that an academic discipline tends to be broad and deep, and it takes a person many years to achieve a high level of expertise in such a discipline."

One of the challenges in taking a college course is to decide what you want to learn versus what the teacher wants you to learn. You know yourself, and you can look into your own mind as

an aid to deciding what you want to learn. However, it is difficult to read the teacher's mind, even if the teacher provides a clear syllabus, assignments, and lectures.

Let me help you read my mind in this particular instance. I am writing a book to help you and other students who are taking college courses. I want you to learn to take increased responsibility for your own learning, and I want you to increase your expertise as a learner.

I, personally, have not memorized my bulleted list that helps to define a discipline. I developed the list over a considerable time, I have used it in several books, and I have revised it a number of times. What I actually carry around in my head is roughly, "the general idea that an academic discipline tends to be broad and deep, and it takes a person many years to achieve a high level of expertise in such a discipline."

However, I have though about the details in the list. I have used them to examine various disciplines that interest me. When I am talking and writing, the word *discipline* has a relatively broad and deep meaning and is an important part of how I view my work. The word is part of me. It is stored in my brain's neurons and I have grown many neural connections that help tie the word in with my other knowledge.

Thus, as an author and teacher, I want the word *discipline* to become part of your working vocabulary—part of you and your worldviews. I want you to have a rich set of neural connections that give meaning to the word in your brain. Memorizing the bulleted list in order to pass a test, and then soon forgetting what you have memorized, contributes very little to your education.

Suppose instead that you select a discipline that interests you and where you have some knowledge and skills. Examine each bulleted item from the point of view of your insights into the discipline. Where are your strengths, weaknesses, interests, and disintersts? What have you done to achieve your current level of expertise in various aspects of the discipline? What helps and encourages you to learn and to increase your expertise in various aspects of the discipline?

Next, do some of the same thinking over again, but now think specifically about how ICT is affecting the discipline and what you know about the discipline. Do you have knowledge of how computers have changed and are changing the discipline? Have any of the courses you have taken in your precollege and college education included a modern discussion of roles of computers in the discipline? Are you skilled in using the Web and other electronic resources to retrieve up to date information in this discipline? What other pieces of software do you know how to use that are relevant to the discipline?

Notice that these are thinking exercises, and you are in charge of doing the thinking. This thinking builds neural connections; it changes your brain! As you think about the questions I have provided, you will likely develop other questions that you feel are more important and more appropriate to you. If that happens and you indeed spend time thinking about a discipline of interest to you, the learning that I want to occur will occur. I cannot guarantee that this will lead to you getting a good grade in a test over this part of the chapter, but likely it will help. I can guarantee if you routinely practice the line of thinking I am encouraging, it will help you to become a more self-responsible and better learner!

Summary and Self-Assessment

One of your goals in school is to increase your level of expertise in solving problems and accomplishing tasks. You now realize that computer technology is a useful aid to solving

problems and accomplishing tasks in every discipline. Thus, as you take courses in various disciplines you will want to increase your ICT knowledge and skills that are relevant to these disciplines. You might think of this in terms of building an island of ICT expertise that is quite specific to a discipline you are studying or a course you are taking.

You are used to the difference between a generalist and a specialist. A generalist tends to have a useful but limited level of knowledge over a very broad range of areas, while a specialist has a very high level of expertise in one specific area. The generalist versus specialist idea even holds within a specific discipline, such as medicine. A general practitioner can handle a wide range of medical problems, but will often refer patients to a specialist. Of course, the specialist has a broad general background, but has far greater depth and experience in one narrow area than does the general practitioner.

As you plan your higher education, think about this idea of generalist versus specialist. What seems to fit best with your insights into yourself and your goals for the future? This type of thinking is useful in any discipline, including ICT. You may want to be a computer science major, perhaps going on to graduate work in this field. Alternatively, you may want to just develop the functional level of ICT knowledge and skills that are or will be useful to you in the various other areas in which you are developing expertise.

Chapter 4.

Human and Artificial Intelligence

"Did you mean to say that one man may acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application, no sooner learns than he forgets?" (Plato, 4th century B.C.)

"If we understand the human mind, we begin to understand what we can do with educational technology." (Herbert A. Simon)

Right now, computers are not very smart. However, steady progress is occurring in making them smarter. Here is an amusing and/or thought-provoking pair of statements:

1. The typical car has an engine rated at approximately 1,000 "person-power." When it comes to physical strength, machines are much stronger than people.

2. The typical modern microcomputer might be rated as approximately .01 "human-brainpower." When it comes to brainpower, people are much smarter than computers. However, computers have by no means reached their upper intellectual limits Some futurists suggest that microcomputers will exceed 1.0 "human-brainpower" sometime in the next 30 years (Kurzweil, 2001).

Measuring computer capacities in terms of "human-brainpower" is suggestive but misleading. In some areas, such as brute force computation, computers are a billion times as capable as human brains. However, it is still a far out, wild prediction to suggest we may have artificially intelligent computers and robots equivalent to a 5-year-old human within 15 to 20 years or so.

This chapter explores educational implications of the cognitive capabilities and limitations of humans and machines. You are very good at some things that computers are not good at, and vice versa. This observation leads us to explore the general idea of humans and machines working together to solve cognitively challenging problems.

Definitions of Intelligence

Ray Kurzweil (2001), a well-known and highly respected futurist, says this about technological change:

An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense "intuitive linear" view. So we won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The "returns," such as chip speed and cost-effectiveness, also increase exponentially. There's even exponential growth in the rate of exponential growth. *Within a few decades, machine intelligence will surpass human intelligence.* [Italics added for emphasis]

One possible beginning point for exploring this thought-provoking and controversial forecast is to examine various widely used definitions of human and machine intelligence.

Human Intelligence

Notice the quote from Plato given at the beginning of this chapter. Attempts to define and measure intelligence have a long and somewhat acrimonious history. Four definitions of intelligence are given in the following quotations.

> Individuals differ from one another in their *ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought.* Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena. (Neisser et al., 1995) [Italics added for emphasis]

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> *Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly, and learn from experience.* It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings— "catching on," "making sense" of things, or "figuring out" what to do. (Gottfredson et al., 1994) [Italics added for emphasis]

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Howard Gardner is well known for his work on a theory of Multiple Intelligences (Gardner, 2003). He describes intelligence this way:

> To my mind, a human intellectual competence must entail a set of *skills of problem solving*— enabling the individual to resolve genuine problems or difficulties that he or she encounters and, when appropriate, *to create an effective product*—and must also entail the potential for finding or creating problems—and thereby laying the groundwork for the acquisition of new knowledge. [Italics added for emphasis]

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Jeff Hawkins founded Palm Computing, Handspring, Numenta, and the non-profit Redwood Neuroscience Institute, a scientific research institute focused on understanding how the human neocortex works. Quoting from the book *On Intelligence: How a New Understanding of the Brain Will Lead to the Creation of Truly Intelligent Machines* (Hawkins and Blakeslee, 2004):

> The brain uses vast amounts of memory to create a model of the world. Everything you know and have learned is stored in this model. The brain uses this memory-based model to make continuous predictions about future events. *It is the ability to make predictions about the future that is the crux of intelligence.* [Italics added for emphasis]

Hawkins is particularly interested in Artificial Intelligence, and his definition reflects this interest. From Hawkins' point of view, intelligence is the ability to make predictions about the future and to take actions that produce desired outcomes. The prediction process requires a continual comparison between what is occurring and what we expect to occur. Intelligence depends on having a memory of past events so that one can compare predictions against past events and the outcomes of past events.

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As mentioned earlier in this book, Robert Sternberg is a world-class expert in human intelligence. He defines intelligence "your skill in achieving whatever it is you want to attain in your life within your sociocultural context by capitalizing on your strengths and compensating for, or correcting, your weaknesses." (Sternberg, 2007) His three-part theory of intelligence focuses on practical intelligence (often called street smarts), school smarts, and creativity.

Sir Ken Robinson is author of the report, *Out of Our Minds: Learning to be Creative*, and a leading expert on innovation and human resources. He defines creativity as "the process of having original ideas that have value." He argues that our educational system at all levels is designed to stifle some important forms of creativity. To learn more about Ken Robinson's insights into creativity:

- View his 19 minute presentation given in 2006, available at http://ted.com/tedtalks/tedtalksplayer.cfm?key=ken_robinson.

- Read the report *Out of Our Minds: Learning to be Creative* at http://www.dfes.gov.uk/naccce/index1.shtml.

In brief, human intelligence is a combination of the abilities to:

1. Learn. This includes all kinds of informal and formal learning via any combination of experience, education, and training.

2. Pose problems. This includes recognizing problem situations and transforming them into more clearly defined problems. (Here, I am using a very general definition of the term *problem*, such as is given in Chapter 3.)

3. Solve problems. This includes solving problems, accomplishing tasks, and fashioning products—ideas discussed in Chapter 3.

4. Be a futurist. This includes accurately forecasting likely outcomes and consequences of one's possible activities. That is, be good in following the dictate, "look before you leap."

5. Be creative in doing all of the above.

Turing (Imitation Game) Test for Machine Intelligence

Alan Turing (1912-1954) was a very good mathematician and a pioneer in the field of electronic digital computers. In 1936, he published a math paper that provides theoretical underpinnings for the capabilities and limitations of computers. During World War II, he helped develop computers in England that played a significant role in England's war efforts. In 1950, Turing published a paper discussing ideas of current and potential computer intelligence, and describing an imitation game that is now known as the Turing Test for AI (Turing, 1950). Quoting from Turing's 1950 paper:

> The new form of the problem can be described in terms of a game which we call the 'imitation game." It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart front the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either "X is A and Y is B" or "X is B and Y is A." The interrogator is allowed to put questions to A and B thus:
>
> …

> We now ask the question, "What will happen when a machine takes the part of A in this game?" Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman? These questions replace our original, "Can machines think?"

The Loebner Prize is an annual contest to determine the best current Turing Test software. Although Turing in his 1950 article predicted that computers would pass the test by 2000, that has not proven to be the case. Ray Kurzweil believes that this event will occur in 2029. The Association for the Advancement of Artificial Intelligence (http://www.aaai.org/AITopics/html/welcome.html) is a good starting point if you want to learn more about the Turing Test and other aspects of AI.

g, Gf, and Gc in Humans and Machines

There is substantial evidence gathered through many years of research that humans possess a general intelligence factor. As noted in Wikipedia:

> Charles Spearman [1863-1945] pioneered the use of factor analysis in the field of psychology and is sometimes credited with the invention of factor analysis. He discovered that schoolchildren's scores on a wide variety of seemingly unrelated subjects were positively correlated, which led him to postulate that a general mental ability, or g, underlies and shapes human cognitive performance. His postulate now enjoys broad support in the field of intelligence research, where it is known as the g theory.

Research on the general intelligence factor has led to a nature-and-nurture theory that divides intelligence into *fluid intelligence* (the nature component) and *crystallized intelligence* (the nurture component). McArdle et al. (2002) describes these concepts this way:

> The theory of fluid and crystallized intelligence … proposes that primary abilities are structured into two principal dimensions, namely, fluid (Gf) and crystallized (Gc) intelligence. The first common factor, Gf, represents a measurable outcome of the influence of biological factors on intellectual development (i.e., heredity, injury to the central nervous system), whereas the second common factor, Gc, is considered the main manifestation of influence from education, experience, and acculturation. Gf-Gc theory disputes the notion of a unitary structure, or general intelligence.

The human brain grows considerably during a person's childhood, with full maturity being reached in the mid to late 20s for most people. Both Gf and Gc increase during this time. While a person's level of fluid intelligence tends to peak in the mid to late 20s, growth in crystallized intelligence may continue well into the 50s.

Since the rate of decline in fluid intelligence over the years tends to be relatively slow, a person's total cognitive capabilities can remain high over a long lifetime. Current research strongly supports the idea of "use it or lose it" for the brain or mind, as well as the rest of one's body (Goldberg, 2005; McArdle et al.; 2002).

One can draw a weak analogy between Gf and Gc for humans and the artificial intelligence of machines. Think of a computer system in terms of hardware and software. The hardware provides the memory, processing speed, and connectivity, somewhat akin to Gf. The software provides content—data and information to be processed—as well as the instructions for processing. This is somewhat akin to Gc. Computers get "smarter" through improvements in hardware and improvements in software.

The Gc of humans comes through life experiences and through formal and informal education and training. Each individual faces the challenge of gaining such knowledge and skill. Contrast this with computer software. A large software development project may involve

hundreds of designers, programmers, testers, and other support staff. Once a piece of software is completed, it can be installed in millions of computers, thus giving all these computers the same level of software capability.

Measuring Intelligence of People and Machines

Human intelligence and machine intelligence (artificial intelligence) are not the same thing. Both are hard to adequately measure, and it is quite difficult to compare these two kinds of intelligence.

Measuring Human Intelligence

Over the past century, there has been considerable research on how to measure intelligence. A wide variety of intelligence measures have been developed and tested for validity, reliability, and fairness. The term Intelligence Quotient (IQ) is a person's mental age divided by the person's chronological age, and then multiplied by 100. IQ tests are usually normed with a mean of 100 and a standard deviation of 15 (most common) or 16.

I hope you did not turn your brain off when you encountered the terms *mean* and *standard deviation* in the previous paragraph. If you have not yet achieved a fluent understanding of these terms, look them up on the Web and work to build your understanding of these widely used components of descriptive statistics.

Figure 4-1 is a short table of data from a normal distribution. (See, for example, http://www.iqcomparisonsite.com/IQtable.aspx.) This table indicates that 68.26 percent of the area under a normal curve lies between –1 and +1 standard deviations. From this table you can deduce that 2.28 percent of the area lies to the left of –2 standard deviations and 2.28 percent lies to the right of +2 standards deviations. Thus, for example, on an IQ test with a standard deviation of 15, only about .37% of people will score 145 or above.

Spread	Proportion of Cases
+ or -1 standard deviation	68.26%
+ or – 1.5 standard deviations	86.64%
+ or -2 standard deviations	95.44%
+ or – 2.5 Standard deviation	98.74
+ or -3 standard deviations	99.74%

Figure 4-1. Normal curve data.

IQ tests are useful and widely used. As Gottfredson (1998) explains:

> The debate over intelligence and intelligence testing focuses on the question of whether it is useful or meaningful to evaluate people according to a single major dimension of cognitive competence. Is there indeed a general mental ability we commonly call "intelligence," and is it important in the practical affairs of life? *The answer, based on decades of intelligence research, is an unequivocal yes.* No matter their form or content, tests of mental skills invariably point to the existence of a global factor that permeates all aspects of cognition. And this factor seems to have considerable influence on a person's practical quality of life. *Intelligence as measured by IQ tests is the single most effective predictor known of individual performance at school and on the job.* [Italics added for emphasis]

However, IQ is only one measure of a person's intelligence, and many people argue about the value of this measure. One obvious flaw is that different IQ tests emphasize somewhat different components of IQ. From the work of Howard Gardner (2003) and others, it is clear that

a person might have substantially different intelligence scores in different areas of intelligence. Put another way, if two different IQ tests place different weights (for example, by using different numbers of questions) on various types of IQ, then a person might well score quite differently on the two tests.

IQ tests do not measure persistence, drive, passion, intrinsic motivation, emotional intelligence, social intelligence, and other traits that make a huge difference in learning, problem solving, and other human activities. Moreover, some people use their intellectual gifts much more effectively than do other people with similar IQs.

The Speed and Quality of Human Learning

The Science of Teaching and Learning provides us with some insights into how to help students learn better and faster. We also know that on average, people with higher IQs learn quite a bit faster and better than people with lower IQs. For the range of students who can effectively participate in the regular classroom environment in precollege education, the lower 5 percent probably learn half as fast and not as well as those with IQs in the mid range, while the upper 5 percent probably learn twice as fast or more, and quite a bit better, than those with the mid range students.

Gottfredson (1998) provides information about the rate of learning of slow learners versus fast learners:

> High-ability students also master material at many times the rate of their low-ability peers. Many investigations have helped quantify this discrepancy. For example, a 1969 study done for the U.S. Army by the Human Resources Research Office found that enlistees in the bottom fifth of the ability distribution required two to six times as many teaching trials and prompts as did their higher-ability peers to attain minimal proficiency in rifle assembly, monitoring signals, combat plotting and other basic military tasks. *Similarly, in school settings the ratio of learning rates between "fast" and "slow" students is typically five to one.* [Italics added for emphasis]

The findings about slower learners versus faster learners are applicable to students in higher education. The typical four-year undergraduate degree program is based on students taking an average of about 15 credits per term. The general expectation is that one credit corresponds to an hour of class meeting per week (actually, 50 minutes) and two hours of study outside of class for each hour in class. Thus, for an average student getting average grades, 15 credits correspond to about 45 hours per week. Students who learn quite a bit faster and better than average are able to carry a significantly heavier course load and learn better than average grades.

Measuring Machine Intelligence

Consider an inexpensive solar battery calculator. It can add, subtract, multiply, divide, and calculate a square root. It takes hundreds of hours of instruction and practice for an average human to learn to reasonably accurately and reasonably rapidly carry out these operations in a paper-and-pencil environment. Moreover, humans are somewhat error prone in using the low tech paper-and-pencil calculation technology.

Thus, one might claim that in doing eight-digit calculations, the inexpensive calculator has more intelligence than a well-educated or well-trained human. I have a calculator that only cost me a dollar. In well under a second, it can tell me that the (positive) square root of 235 is 15.329709.

Of course, my calculator has no "understanding" of what a square root is. It does not know about mathematical functions and that a square root is a mathematical function with a wide range of uses. One of the uses is in determining the length of one edge of a right triangle, given the lengths of the other two edges. This involves knowing the Pythagorean theorem. My calculator does not know about surveying land to determine the corners of a plot of land after a flood. It does not know about the Nile River, the ancient Egyptians, and so on.

The point is that computer hardware and software can be developed to solve or help solve a wide range of problems that previously required human intelligence to solve. However, this does not give us much insight into the intelligence of a computer system or how to measure machine intelligence.

Some researchers in AI have put a tremendous amount of effort into developing and studying chess-playing computer systems. IBM even designed computer hardware that would be especially fast in analyzing chess moves. In 1997, this computer system (a combination of hardware and software named Big Blue) defeated Gary Kasparov, the reigning human world chess champion.

Wow! That certainly impressed some people. Of course, Big Blue did not know what a human being is, what a game is, the thrill of victory and the agony of defeat, why people enjoy learning how to play a game such as chess, why it took Gary Kasparov tens of thousand of hours of effort to become world champion, and so on.

Some people continue to put considerable effort into developing better computer chess programs. The best of such programs, playing on a typical modern microcomputer, are playing at roughly the same level as the top human chess players in the world (Andrews, 2007).

Consider a simple personal computer equipped with computer-assisted learning (CAL) software designed to help a human get better at fast keyboarding. The software provides instruction that has been carefully designed by one or more humans. The computer system can keep track of the performance of each finger of the human keyboarder. If a particular finger or combination of fingers is somewhat slow or inaccurate, it can adjust the training to give specific help to the finger or combination of fingers. It can provide an appropriate combination of speed drills and accuracy drills to help the user gain both speed and accuracy.

In summary, it is possible to develop keyboarding CAL that can outperform a good human tutor in certain areas, and that is as good as an individual human tutor in other areas. Do you have pity for all of the humans who used to teach typing? Perhaps you should. If you do a Google search on *free typing tutor,* you will see that part of what typing teachers used to do for a living can now be done by software that is available free on the Web. The AI of keyboarding CAL has proven sufficient to substantially change the jobs of humans who teach typing (keyboarding).

Do you know your current keyboarding speed? Free software is available on the Web that can assess your keyboarding skills. See, for example, http://www.northcanton.sparcc.org/~technology/keyboarding/freeware.html. If you are unsatisfied wit your speed, select one of the free self-instruction tutorials and spend a few hours of a few dozen hours practicing.

To carry the keyboarding example further, consider voice input systems. Voice input has proven to be a challenging AI problem. However, this task has been solved well enough so that

many people now use voice input. When the user detects a computer voice recognition error, use of voice input and/or a keyboard and mouse can correct the error. Voice input systems get better (smarter, more intelligent) through continued research and the development of better hardware and software. A system can also get better by training itself to a particular user's voice. Voice input is now good enough that it has wide commercial uses.

All of the examples given above fall into what is called *weak AI*. Contrast this with *strong AI*. As explained in Wikipedia:

> In the philosophy of artificial intelligence, strong AI is the supposition that some forms of artificial intelligence can truly reason and solve problems; strong AI supposes that it is possible for machines to become sapient, or self-aware, but may or may not exhibit human-like thought processes. The term strong AI was originally coined by John Searle, who writes: "according to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind."

Ray Kurzweil and the others see the steady progress in weak AI and agree it will continue. Ray Kurzweil believes we will have strong AI that far exceeds human intelligence before the year 2050. Others believe that we will never have strong AI that in any sense rivals the intelligence of humans.

The educational implications of this issue are immense. Pick any academic discipline and the problems it addresses. Now, divide these problems into two categories. Into the first category, place the problems where a properly educated and trained person working with the best of current AI systems can substantially outperform an equally well-educated and well-trained person who does not have access to the computer systems. The second category of problems contains those where current levels of AI do not make an appreciable difference.

Now think about the first category of problems steadily increasing in size through a combination of steady progress in weak (and possibly strong) AI and through improved education for people who will work in this collaborative environment. That describes the world as it is today and in the future. You are living during a time of continual and substantial increase in the capabilities of computer systems.

Our educational system is struggling with what it should be doing about this change. You, personally, face the challenge of getting an education that helps prepare you for a future of steady increase in machine intelligence.

Human and Machine Memory

It is clear that memory is an important aspect of intelligence. Here is a repeat of the quote from Hawkins and Blakeslee (2004) given earlier in this chapter:

> The brain uses vast amounts of memory to create a model of the world. *Everything you know and have learned is stored in this model. The brain uses this memory-based model to make continuous predictions about future events*. It is the ability to make predictions about the future that is the crux of intelligence. [Italics added for emphasis]

One of the advantages that computers have over humans is their ability to quickly store and quickly retrieve large amounts of information. We are impressed by a person who can memorize a book or a musical performer who can memorize music that totals tens of thousands of notes in length. Such memorization takes considerable time and effort. Contrast this with storing information on a 300-gigabyte computer disk at the rate of many millions of bytes per second.

Such a hard disk and its disk drive can now be purchased for under $100—and can store the equivalent of 300,000 full-length novels.

In 1956, George A. Miller published a seminal paper about human memory: "*The Magical Number Seven, Plus or Minus Two*: *Some Limits on Our Capacity for Processing Information*. The unifying theme in this paper is that for a typical person, short-term working memory can only store about five to nine chunks of information. This means, for example, that a typical person can read or hear a seven-digit telephone number and remember it long enough to immediately key it into a telephone keypad.

Here are descriptions of three different types of human memory:

- **Sensory memory** stores data from one's senses, and for only a short time. For example, for most people visual sensory memory stores an image for less than a second and auditory sensory memory stores aural information for less than four seconds.

- **Working memory** (short-term memory) can store and consciously, actively process a small number of chunks of information. It retains these chunks for less than 20 seconds.

  One can draw a parallel between the central processing unit (CPU) of a computer and the working memory of a human. The CPU has some storage used in processing pieces of information, so it can be thought of as both a storage and a processing unit.

- **Long-term memory** has large capacity and stores information for a long time. Human long-term memory is both a storage and a processing system. Millions of neurons may be working together (in parallel) to carry out a task.

  The analogy between computer long-term memory (such as disk memory) and human long-term memory is not a good one. It is not correct to think of a specific neuron as storing a specific chunk of information or one byte of data. Moreover, the processing done by a human brain is not like the processing done by a digital computer. A human brain stores and processes patterns, using a large number of neurons to store a pattern and a large number of neurons when it is processing a pattern or group of patterns.

Working memory has a quite limited capacity. However, the research on expertise by Ericsson (n.d., in press) and others indicates that experts train their long-term memory in their areas of expertise so that it has some of the characteristics of working memory. One way to think about this is that working memory processes information at a conscious level and long-term memory processes information at a subconscious level. By dint of thousands of hours of study and practice, one can gain a certain amount of conscious control over parts of one's long-term memory.

Artificial Intelligence

As noted earlier in this chapter, many AI experts like to distinguish between weak AI and strong AI. Some see us moving toward AI systems that can far exceed the mental capabilities of people. It is important that educators and students understand some of the mechanisms for increasing AI and areas of weakness of AI relative to human intelligence.

Rote Memory

The discussion of computer memory and CPUs gives us part of the foundation needed to discuss ways of increasing the AI of computer systems. Suppose, for example, that IQ depended

mostly upon having a large memory that could quickly memorize and regurgitate what it has memorized, and that does not forget over a period of many years. With that measure, computers beat people hands down. Moreover, we are still in a technology development phase in which the cost effectiveness of computer storage devices is improving very rapidly. In addition, the Internet makes it possible for hundreds of millions of people to access the Web, a huge and rapidly growing virtual library.

Rote memory is an important component of increasing expertise in a variety of disciplines. For example, a world-class chess player must memorize many thousands of sequences of opening moves and end game moves. However, the number of different sequences of possible moves in a chess game overwhelms a human's rote-memory approach to achieving a high level of expertise. Indeed, it overwhelms a computer's rote-memory approach. A computer can easily memorize a trillion different sequences of chess moves. However, that is a very small number relative to the number of different sequences of moves possible in a chess game.

Algorithmic and Heuristic Procedures

An algorithmic procedure is a step-by-step procedure that can be proven to succeed in the task it is designed to accomplish. For example, you know an algorithm for multiplying multi digit numbers. To increase the weak AI of a computer, problem situations can be analyzed and new or better algorithms can be developed.

A heuristic procedure (often called a rule of thumb) is also a step-by-step procedure, but not one that can be proven to always work. We all frequently use heuristic procedures. Before I walk across a one-way street, I look in the direction from which the traffic is coming, in order to avoid getting hit by a car or a bicycle. However, this heuristic procedure fails if a car or bicycle is driving the wrong way on the road. It may also fail me if a car pulls out of a nearby parking lot immediately after I have checked for traffic.

Much of the recent progress in weak AI has been in developing better heuristics. A typical AI program contains a combination of algorithms and heuristics. A spelling checker uses an algorithmic procedure to see if a word is in its spelling dictionary. If a word is not in the dictionary, a heuristic procedure is used to suggest alternative words or spelling. I increase the intelligence of my spelling checker when I add words to my custom dictionary.

Grammar checking is a far harder problem than spelling checking. At the current time, grammar checking is based on a combination of algorithms and heuristics, and the results are only of modest quality. Current levels of Weak AI are not well suited to the task of grammar checking.

Voice input to computers is a relatively difficult AI problem. It has gradually gotten better as better heuristics have been developed.

Language translation is a really hard problem. Current levels of success are still rather modest, but significant progress is occurring (Tanner, 2007). The language translation problem gives us some interesting insights into the power of a human brain. Material to be translated comes into one's brain through reading or listening. The brain translates this into meaningful ideas. Then the brain translates these meaningful ideas into a target language and produces the output. The key is that the brain understands the meaning of the input materials. Such understanding by a computer would require strong AI. Current computerized language translation systems do not have an understanding of the meaning of what they are translating.

Machine Learning

Still another way to increase the intelligence of a computer system is to have the computer system actively involved in learning on its own. For example, to develop a better chess-playing program, the program can use the analyses that have been carried out by chess masters, and can also "study" thousands of games that have been played by chess masters. A somewhat similar approach can be used in developing computer systems that can carry out medical diagnostic tasks. In both the chess-playing and medical diagnostic work, the computer studies what actually occurred (the game or the actual diagnosis, along with the medical data that was gathered) and then uses the outcomes (who won, whether the treatment based on the diagnosis worked).

Computer-Based Chunks

An earlier part of this chapter mentioned George Miller's 1956 seminal paper about human memory: *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information.* Chunking—organizing information into chunks—is an essential aspect of dealing with this limitation.

My long distance University of Oregon phone number used to be 1-541-346-3564. I chunked it as "long distance," "my local area code," "my university preface," and the last four digits 3 5 6 4. In total, this is just seven chunks.

Pencil; and paper are a powerful aid to cognitive overload (that is, an overload of working memory). However, training and experience are also a powerful aid. Quoting George Miller:

> A man just beginning to learn radio-telegraphic code hears each dit and dah as a separate chunk. Soon he is able to organize these sounds into letters and then he can deal with the letters as chunks. Then the letters organize themselves as words, which are still larger chunks, and he begins to hear whole phrases.

Each academic discipline develops it own special vocabulary and notation in a manner that facilitates chunking. A physicist might make use of the expression $E = mc^2$ as a single chunk, and a high level chess play might consider a particular placement of a half dozen pieces on a chess board as one chunk. One aspect of gaining a high level of expertise in a discipline is learning chunks and to learn to think using these chunks.

An inexpensive six-function calculator contains a key labeled with symbols such as $\times$, $+$, and $\sqrt{}$. Each can be thought of as a chunk—in this case, a symbol representing an arithmetic algorithm that the calculator can carry out. A scientific calculator provides many more chunks, while a computer provides still more chunks. For example, if one is familiar with the graphing capabilities of spreadsheet software such as Microsoft Excel, then a graph such as a bar graph, pie chart, or scatter plot is a single chunk. In some sense, learning calculator or computer chunks is somewhat like learning the words in a new language. Learning to think using such chunks is like learning to think in a new language.

Expert Systems

Earlier parts of this book have discussed expertise and islands of expertise. Computer scientists use the term *expert system* in discussing the development of AI-based islands of expertise. Quoting from the Wikipedia:

> An expert system, also known as a knowledge based system, is a computer program that contains some of the subject-specific knowledge, and contains the knowledge and analytical skills of one or

more human experts. This class of program was first developed by researchers in artificial intelligence during the 1960s and 1970s …

Some of the early success of expert systems was in medical diagnosis. A narrow problem area is selected, such as the diagnosis of infectious diseases. One or more human experts work with knowledge engineers to develop a computerized diagnostic system. The system is then tried out using data from many different patients who previously were diagnosed by human experts. The successes and failures by the computer system are used to modify the program so that it is more accurate. This process can also be somewhat automated, by having the computer system study case histories. The results in various narrow fields of medicine have been quite good—equaling or exceeding the expertise of well-qualified human doctors. However, such systems have seen only limited use in the actual world of medical practice. One reason is liability risks. Even well prepared medical doctors make mistakes—but in that case, there is a human being to whom to assign blame and perhaps to sue.

There is less concern in areas such as deciding whether to make a loan to a bank customer and in thousands of other situations where the islands of expertise provided by expert systems are now in routine use. My Google search using the quoted expression *"expert system"* produced 191 million hits.

Summary and Self-Assessment

You can maintain and even increase your intelligence by keeping yourself physically and mentally fit, and by your explicit efforts to increase your crystallized (Gc) intelligence. You can also improve your overall physical and cognitive capabilities by learning to make use of effective aids. This book focuses specifically on encouraging you to learn to make effective use of ICT systems. This chapter focuses specifically on the auxiliary brain/mind aspects of artificial intelligence.

Weak AI systems can solve a variety of cognitive problems and accomplish a variety of cognitive tasks. In some of these problems and tasks, AI systems readily outperform humans. However, the weak AI we currently have is substantially different than human intelligence.

At the current time, there are thousands of researchers and programmers working to improve the software and underlying theory of weak and strong AI. When any significant progress occurs, it can be widely disseminated and readily implemented on millions of different microcomputers.

It is evident that weak AI will continue to improve. However, weak AI tends to be domain-specific in that a particular AI system deals with a narrow range of problems. It also tends to be quite limited in the problem areas that require understanding of human language and what it means to be human being.

ICT presents both threats and opportunities. The development of intelligent machines is still in its infancy. By and large, even the people of the best-educated nations of the world are having difficulty dealing with this steady (and increasing) pace of change. My advice to you to think carefully about (that is, self assess) how well you are doing in each of the following;

1. Know your own physical and cognitive capabilities and limitations. Work to maintain and improve your physical and cognitive capabilities, and learn to make accommodations for your limitations.

2. Know the physical and AI machine capabilities and limitations of computer systems and computerized machines. Pay particular attention to the increasing

capabilities of search engines on the Web and of software that can solve problems and accomplish tasks that previously required human intelligence.

3. Plot a lifelong path that is consistent with your own interests, drives, intrinsic, and extrinsic motivation and opportunities, and that takes into consideration your insights into 1-2 given above. Be fully aware that during your life, both you and machines will change.

Chapter 5

Computer-Assisted and Distance Learning

"Through learning we re-create ourselves. Through learning we become able to do something we never were able to do. Through learning we re-perceive the world and our relationship to it. Through learning we extend our capacity to create, to be part of the generative process of life. There is within each of us a deep hunger for this type of learning." (Peter Senge, 1990)

Distance learning (DL) refers to teaching and learning situations where the teacher and the students do not come together in face-to-face meetings. The roots of current DL lie in correspondence courses where interaction between the teacher and students was carried on using surface mail. Such instruction predates computers. Now, interaction is facilitated by electronic means such as email, the Web, and telephones.

Computer-assisted learning (CAL)—sometimes called computer-assisted instruction—refers to teaching and learning situations in which a computer system provides interactive instruction. I find it helpful to think of this as the computerization of some of the SoTL knowledge, teaching skills, and management skills of human faculty members.

Nowadays it is becoming increasingly common for CAL to be delivered over the Web. That is, we are seeing a gradual merger of the ideas of DL and CAL. If you make use of the Help features on a computer, you are making use of one form of CAL. Sometimes a Help feature will draw information from a website, and then you are using both CAL and DL.

In addition, we are witnessing a paradigm shift in education, with an increasing number of students using CAL and DL for all or part of their higher education. Such forms of instructional delivery are also widely used in precollege education.

Feedback and Learning

Feedback is an important component of the Science of Teaching and Learning (SoTL) and is essential to learning. Thus, the design of effective instruction is heavily dependent on designing and providing effective feedback. Note, however, that our educational system is not nearly as good as it could be in implementing what we know about feedback. As Walt Haney (1991) notes:

> Common sense, theories of learning, and research on intrinsic motivation … all clearly indicate that the sort of standardized testing now commonly employed in schools and via which students do not get rapid or specific feedback on their work … is simply not conducive to learning.

Feedback that is essential to learning can come from inside or outside the learner. For example, if you listen to a small child babbling, perhaps making random sounds, you may sense that the child is gaining intrinsic internal feelings of pleasure in the process of making the

sounds. This is an example of internal feedback. A mother or father may hear sounds that are vaguely similar to *ma* or *pa*. The parent immediately provides feedback, including guidance on better pronunciation of the sounds, enthusiasm, a broad smile, and other responses. This is an example of external feedback. The child eventually learns to make the ma or pa sounds at appropriate times, driven by some combination of intrinsic and extrinsic motivation.

Internal (Self-Provided) Feedback to the Learner

Think about the situation of when you are reading and attempting to learn from an academic paper. The paper presents research results in a format that meets the standards of a particular discipline or journal. Typically, the format and standards are not particularly well designed to help learners, especially, learners who have a very low level of expertise in the discipline.

As you read, you think about (reflect on) what the article says. You test what it says against what you already know. You ask yourself questions to check on your growing knowledge. You reread sections that seem unclear or in order to better answer the questions you are asking. You are actively engaged in constructing new knowledge inside your brain, and you are actively engaged in providing feedback to yourself.

How did you develop these reflective, self-feedback skills? What could your teachers have done to better help you gain such skills and help improve the quality of these skills? Are the college students you teach skilled in this type of reading, reflective, metacognitive processes?

Here is another example. Suppose you successfully solve a problem or complete a task that was personally challenging. During the process and afterward, do you do metacognition on the process and consider what you learned during the process? Do you think about what went right, what could have been done better, and what you learned? Metacognition and reflection are forms of self-feedback that you can engage in at any time and that will help you learn.

Feedback Coming from Outside the Learner

Much of the feedback that is essential to learning comes from external sources. There are many different types of such external feedback sources. A teacher asks the class a question, a number of students raise their hands volunteering to provide an answer, and one student provides an answer. However, all students have thought about whether they can provide an answer, and many have mentally rehearsed an answer. As the one student provides an answer, the attentive listeners use the information to check their own answers.

There are many ways to improve feedback from students to the teacher and from the teacher to students in a large lecture-hall situation. Eric Mazur (n.d.), a physics professor at Harvard, has developed a reputation for his innovation and research in this area. As he notes:

> Class time is a precious commodity, but how often do we stop to think about how it's being used? Should class activities merely transmit information that is already printed in the students' textbook? Do our students actually *learn* during class, or do they simply feverishly scribble down everything we say, hoping somehow to understand the material later?
>
> We are investigating ways that instructors can enhance student understanding, by promoting active learning in the classroom and pursuing strategies that meet the needs of diverse students.

Mazur and many other course instructors are now having their students use a handheld response unit (a "clicker") with which they respond to multiple-choice questions. A computer and projection system accumulate the responses and display the results. This is a good example

where the use of computer technology can improve feedback both to the students and to the teacher in a large lecture setting.

Feedback and Instructional Design

There has been considerable research on feedback and learning. B. F. Skinner is well known for his behaviorist work in operant conditioning (stimulus, response, and immediate feedback) as a form of teaching. In more recent times, cognitive learning theories have proven more appropriate to the design of curriculum for use in precollege and higher education.

As Steven McGriff (n.d.) explains:

> Under cognitive learning theory, it is believed that learning occurs when a learner processes information. The input, processing, storage, and retrieval of information are the processes that are at the heart of learning. The instructor remains the manager of the information-input process; but the learner is more active in planning and carrying out his/her own learning than in the behaviorist environment. *Instruction is not simply something that is done to a learner but rather involves the learner and empowers their internal mental processes.* [Italics added for emphasis]

A commonly used instructional process is to have students interact with each other in small, cooperative learning and discussion groups. Such small-group interactions facilitate student engagement and let students provide feedback to each other. Such collaborative learning can go on in a classroom setting, but it can also go on in ICT-mediated communication.

Distance Learning

Here is a tidbit of history on distance learning (often referred to as distance education) from McIsaac and Gunawardena (1996):

> Distance Education is not a new concept. In the late 1800s, at the University of Chicago, the first major correspondence program in the United States was established in which the teacher and learner were at different locations. Before that time, particularly in pre-industrial Europe, education had been available primarily to males in higher levels of society. The most effective form of instruction in those days was to bring students together in one place and one time to learn from one of the masters. That form of traditional educational remains the model today.

Actually, distance education has existed since the time of the first available written materials. A book is an excellent vehicle for teaching and learning. The book's author and the learner can be separated in terms of time and distance. The reader plays a major role in providing the feedback needed in learning from a book.

Learning by Reading

In U.S. elementary schools, there is a commonly accepted goal of having students learn to read well enough by the end of the third grade so that they can begin to learn by reading. By about the sixth or seventh grade, the assumption is that students will gain a substantial portion of their education by reading. However, students vary widely in how well they can learn through reading. This is an especially important issue in higher education, where the assumption is that students can and will do the required reading and will learn through this process. This is often a mistaken assumption.

In the past year or so, I have read quite a bit of research literature on students learning through reading. It turns out that there is a significant difference between being able to read and being able to read well enough so that one can readily learn by reading. This is particularly true

in material that requires careful attention to details and that focuses on higher-order cognition. There is a huge difference between reading a math or physics book and reading a novel.

This situation provides an excellent example of when where you should be taking increased responsibility for your learning. How good are you at reading? Are you comprehension levels and speed of reading in various disciplines appropriate to your needs? If not, what are you doing about it? There are many free sources of help on the Web, and most colleges and universities have student learning centers that can provide free help.

Improving Feedback in DL

Correspondence courses (making use of surface or air mail) have a relatively slow rate of interaction between a student and the teacher. However, they do force students into a learn-by-reading mode. Moreover, the nature of the feedback available through correspondence with an instructor places increased emphasis on students learning to provide feedback to themselves.

Of course, it is possible to design written materials specifically to aid students in their learning processes. Historically, distance education became more formal when print materials were developed that contained detailed lessons and assignments to be completed. Feedback might come from an answer key or through asking students questions that required higher-order thinking processes to formulate written answers to be mailed to an instructor.

The development of the telephone and two-way radio added a new dimension to DL because the teacher and student could converse with each other from time to time. DL delivery via television, perhaps with the aid of a telephone connection to individual students or a room full of students, led to a significant increase in its use.

The nature and quality of feedback available through a well-designed DL course can equal or exceed that which is available to students in a traditional large- or medium-sized lecture course. However, many of the types of feedback that can go on in a classroom setting are different from the types of feedback that are possible in a DL course. Thus, when students first encounter DL courses, they face the added challenge of learning to accept and use the types of feedback that are available through DL.

This observation is an underlying source of weakness in much of the DL research. Students spend many years learning to learn in a teacher-led classroom environment. The students then take a DL course, and their learning is compared to the learning of students in the traditional classroom. I find it somewhat surprising that even without the years of experience in DL, the typical result in such studies is that there is no significant difference between the amount of learning that takes place in the two types of courses. Thomas Russell (n.d.) has developed a Website devoted to this "no significant difference" phenomenon. It is a good source of research literature on the topic.

Asynchronous and Synchronous DL

Correspondence courses are asynchronous—students work on a time schedule that fits their own needs and they work independently of each other. This situation changed when radio broadcasts and, later, TV broadcasts became a common component of DL. The student had to listen to the radio or view the TV when the broadcast was occurring. This synchronous instruction was combined with asynchronous work on assignments, which were mailed to the instructor.

Of course, as tape recorders and inexpensive VCRs became available, tapes could be mailed to the student or the student could record a program for later use. Thus, the use of radio and TV delivery was easily converted to allow for asynchronous DL.

In formal school settings, it became relatively common to have students who were taking a TV-delivered course to meet in classrooms that had a telephone connection to the instructor. A few students could ask questions during the time of a lecture or demonstration. This is not unlike the "call in" radio and TV programs that are now quite common.

Now it is common to use two-way video so that a DL instructor can see and talk to students located at a distance, and vice versa. This type of synchronous instruction is somewhat classroom-like, but a teacher may be simultaneously working with several groups of students from different locations.

Initially, this type of two-way video connectivity was relatively expensive. As Internet II and other high-speed networks have become more common, the cost of connectivity in this type of synchronous DL has decreased substantially.

As email became available, asynchronous email-based distance education courses were developed. The email made it easier and quicker for students to interact with the instructor and each other.

More recently, Internet chat groups and Web-based two-way video have significantly changed distance education. While the postal services throughout the world are still used for some DL, the Internet has greatly expanded the use of DL.

Finally, we come to the current situation. The Web can be used to hold ordinary telephone conversations and conduct video interactions. Thus, the Web can be used to deliver synchronous DL. Of course, the Web can also be used to deliver asynchronous DL, with students having access to multimedia course materials at a time that fits their convenience.

The use of asynchronous and synchronous DL is steadily increasing. One can get a high school education, college education, and even a master's and doctorate degrees through accredited DL programs.

Learning in a DL environment is different from learning in traditional school classrooms, where one has daily face-to-face communication with fellow students and the teacher, and the class as a whole follows the same time schedule. Skill in learning via DL is now considered a valuable lifelong skill. Some people are now recommending that all students should take part of their precollege education and college education via DL so that they will gain the knowledge and skills needed to learn in this environment. I am one of the people making this recommendation to students.

Computer-Assisted Learning

Think about the various roles played by faculty members and students, and their interactions in the overall teaching and learning process. Then think about what aspects of these roles and interactions can be aided or facilitated by computer technology. Whatever you can think of probably is part of the fields of computer-assisted learning (CAL) and DL.

Use of Simulations—Early and Continuing Success

People have been thinking about CAL since the early days of the development of the electronic digital computer. A major initial success occurred as the U.S. developed and deployed radar systems that were designed to detect airplanes and missiles in route to the U.S. from the U.S.S.R. The whole radar system was highly computerized. Operators sat at computer display screens that provided information about what the radar systems were detecting and what computer analysis of these signals was showing.

From the point of view of an operator, it is not possible to determine from current radar readings being processed through computers whether the displayed information is live or simulated. The simulated displays could be from stored radar readings or could be simulations created specifically to help train the operators.

This type of very highly realistic CAL works very well. There is now a long history of the use of simulation-based CAL in training airplane pilots, astronauts, tank crews, nuclear reactor operators, and so on. Generally, use of such simulations is more effective, more cost effective, and less dangerous than other applicable forms of instruction. There is quite a bit of simulation-type CAL available commercially (Laser Professor, n.d.).

Less Expensive CAL

As computers became less expensive, many people developed and tested a wide variety of forms of CAL. It is quite easy, for example, to develop a drill-and-practice system that is better than just using flash cards that have a question on one side and an answer on the other side. A computer system can keep detailed data on correct and incorrect responses and the speed of the various responses. It can detect patterns of errors. It can stop the drill-and-practice activity and insert specific instructions on a topic that is causing the student trouble. It can increase or decrease the difficulty of the questions.

More sophisticated CAL systems—often called tutorial systems—can present instruction interspersed with questions. The student responses provide information that shapes the instruction. Tutorial CAL systems are a little bit like having an individual human tutor.

An individual human tutor has good knowledge of both content and pedagogy. The human tutor builds a mental model of the student's knowledge and skills. The human-based tutoring instruction fits constructivist learning theory and includes immediate feedback. Wouldn't it be nice if every student could have a personal tutor who was competent in each subject area of interest to the student and available on a round-the-clock basis?

It is easy to understand why so many people have thought about CAL as a vehicle to revolutionize education. Over the years, thousands of CAL systems were developed and many hundreds of research projects were carried out on these products. Eventually people began to do metastudies—studies of the studies. Finally, enough metastudies had been done so that it was feasible to do a meta-metastudy. The first meta-metastudy of CAL, conducted by James Kulik (1994), provided strong evidence of the effectiveness of CAL, with students (on average) learning via CAL 30 percent faster and somewhat better than students in control groups.

Here are four major barriers to the widespread use of CAL in higher education:

1. A human tutor can interact with students orally. We are still many years (perhaps two to three decades or more) away from having computer systems that carry on a

high-level, deep conversation at a human level of understanding. (Such a tutorial system would be able to pass the Turing Test.) However, the quality of voice input/output is improving and now has a number of commercial uses.

2. High-quality, highly interactive CAL is quite expensive to develop. My personal insight into this area suggests that it costs about $5 million to develop a high quality, semester-length course. Maintaining and regularly updating such a course costs about $1 million a year.

   These costs are modest for high-enrollment courses, if one considers the total national or international enrollment in such courses. In the U.S., there are enough students beginning college each year so that it would be economically feasible to have a half dozen or more competing CAL courses in each of several different subject areas.

3. Education is far more than just the delivery of instruction and learning of content. Residential colleges and universities provide an environment that facilitates students learning about the human condition, their own culture, and other cultures, as well as how to interact with people in many different settings, how to work together in teams, and how to learn from each other.

4. Our educational system has a life and character of its own. Its employees, volunteers, students, and graduates all have a vested interest in preserving our educational institutions and system in their current format. Our educational system is innately highly resistant to change.

Hybrid Courses

The term *hybrid course* is used to describe a course that is some combination of traditional class meeting time (perhaps enhanced by appropriate use of technology during the class meetings), CAL, and DL.

The Open University in England provides a good example of an entire university based on DL along with some hybrid courses. This university was established in 1969. Television and videotapes originally were the primary mode of instructional delivery. However, courses that traditionally included lab work (such as science courses) scheduled the labs at various colleges and universities, and were thus hybrid courses..

As described in Wikipedia:

> The [Open] University awards undergraduate and postgraduate degrees, diplomas and certificates.
>
> With more than 180,000 students enrolled, including more than 25,000 students studying overseas, it is the largest academic institution in the UK by student number, and qualifies as one of the world's mega universities. Since it was founded, more than 3 million students have studied its courses. *It was rated top University in England and Wales for student satisfaction in the 2005 and 2006 UK government national student satisfaction survey.* [Italics added for emphasis]

The Open University was originally developed mainly to serve students who had previously participated in a vocationally oriented track of secondary school education. A substantial amount of money was invested in developing the courses (perhaps $1 million per course during the 1970s) and keeping them up to date. This large and continuing investment may help explain the high level of student satisfaction mentioned in the quote above.

Open Education Resources

Most students find it quite painful to have to buy textbooks for their courses. They find the costs completely unreasonable. The movement toward substantially increasing the use of DL and CAI is being aided by a variety of Open Education Resources (OER) movements. The OER (n.d.) Website describes OER materials this way:

> OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge.
>
> …
>
> *At the heart of the movement toward Open Educational Resources is the simple and powerful idea that the world's knowledge is a public good and that technology in general and the Worldwide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse knowledge.* OER are the parts of that knowledge that comprise the fundamental components of education—content and tools for teaching, learning, and research. [Italics added for emphasis]

Final Remarks

Right now, the majority of formal education is still carried out in the "traditional" manner of bringing students together in classes taught by a faculty member. However, CAL, DL, and hybrid courses are beginning to take a significant bite out of this approach.

There are several keys to the change that is occurring:

1. Highly interactive intelligent computer-assisted learning is getting better. In a variety of situations, it produces better learning results than tradition modes of instruction. Improvements in feedback to the learner are key to this.

2. As use of DL-based CAL learning increases, students will gradually learn to learn in this environment. Many will find that an asynchronous learning environment is well suited to their learning needs. Students can learn to provide better feedback to themselves and to take increased responsibility for their own learning.

3. There is a potential economy of scale and economy of not maintaining large, expensive physical campus facilities. Many colleges and universities are currently struggling to find a right mix between traditional and new modes of instruction that will best serve them and their students.

Self-assess your current experiences in CAL, DL, and hybrid courses, Help features on a computer, and other non-traditional aids to learning. What are you doing to gain increased expertise in learning in such learning environments?

Chapter 6

Learning and Learning Theory

"They know enough who know how to learn." (Henry Adams)

"In short, learning is the process by which novices become experts. " (John T. Bruer. Schools for Thought, 1999, page 13.)

The previous chapter included some discussion about intrinsic and extrinsic motivation, and it emphasized the necessity of feedback in learning. These topics are part of *learning theory*.

ICT creates some new aids to learning and it creates some new challenges to learning. However, it does not obviate what was known about learning theory and good learning practices before computers became so readily available.

This chapter introduces topics that will be of considerable value to you during your college education and throughout the rest of your life. Most of the topics covered are quite general, rather than being specific to ICT. All of the ideas in this chapter have been discussed in books that I have written for elementary and secondary school teachers. For some reason, our educational system thinks that teachers should know about these ideas, but that they are not part of the regular curriculum for students who do not plan to become teachers. In my opinion, our educational system should include all of these topics in the curriculum that all students study.

Cognitive Developmental Theory

We know that the human brain changes quite rapidly during early years of life, and it continues to change at a significant rate until we are in our mid 20s. Thus, the brains of many younger college students have not yet reached their full maturity.

There has been a lot of research on how a person's brain develops over time, and the capabilities of an average brain at different stages of this development.

Jean Piaget's work on cognitive developmental theory has contributed greatly to our understanding of the stages of human development. (Huitt & Hummel, 2003). Piaget developed a theory of four-stage cognitive development that is still widely used. Figure 6-1 outlines the stages and developments Piaget proposed. As you study this scale, think about how well it describes your own cognitive development.

Approximate Age	Stage	Major Developments
Birth to 2 years	Sensorimotor	Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. If the environment (nurturing, food and vitamins, shelter, freedom from lead and other poisons, healthcare) is adequate beyond some modest threshold, then developmental progress is strongly dependent on genetic/biological factors.
2 to 7 years	Preoperational	Children begin to use symbols, such as speech. They respond to objects and

		events according to how they appear to be. Children make rapid progress in receptive and generative oral language. There are large advantages to growing up in a cognitively rich and challenging cultural and socioeconomic environment.
7 to 11 or 12 years	Concrete operations	Children begin to think logically. In this stage (characterized by seven types of conservation: number, length, liquid, mass, weight, area, and volume), intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking—including mental actions that are reversible mental testing of ideas—begins to develop. Schools and schooling play a significant role in helping to shape a child's development during this stage.
11 or 12 years and beyond	Formal operations	Thought begins to be systematic and abstract. Reasoning takes place deductively and theoretically, from hypothetical situations to the concrete. Understanding the concept of probability occurs. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. Examples include reading with a high level of comprehension in typical courses at the high school level, and representing, understanding, and solving algebra, geometry, and other math problems at the level of high school math courses.

Figure 6-1. Piaget's cognitive development scale.

A student's rate of progress through the Piagetian developmental stages is dependent on both nature and nurture. Good and cognitively rich home, neighborhood, community, and school environments make a huge difference.

Formal operations is a broad concept. Each discipline tends to make up its own definition of what constitutes the achievement of formal operations within its own discipline. It takes education and experience to learn the vocabulary, notation, symbols, and methods of reasoning used in a specific discipline. We say that a person has achieved formal operations in a specific discipline when the person has achieved a reasonably high level of expertise in thinking and problem solving within the discipline.

Different disciplines use different vocabulary in talking about a person's developmental level. In mathematics, for example, it is common to talk about a person's level of *math maturity*. Indeed, college course descriptions sometimes indicate that math maturity is the prerequisite for a particular computer science, science, or math course. In essence, the requirement is that a student be at formal operations in math.

Having a high level of math maturity refers to having a high level of being able to represent problems mathematically, understand, think, reason in the language of mathematics, and solve challenging math problems within a realm of the math one has studied. Thus, it is appropriate to talk about a fifth grade student having a high level of math maturity relative to other fifth grade students.

Research in the past couple of decades indicates that movement into formal operations is not automatic. As Huitt and Hummel (2003) note:

> Data from similar cross-sectional studies of adolescents do not support the assertion that all individuals will automatically move to the next cognitive stage as they biologically mature. Data from adult populations provides essentially the same result: Between 30 to 35% of adults attain the cognitive development stage of formal operations (Kuhn, Langer, Kohlberg & Haan, 1977). *For formal operations, it appears that maturation establishes the basis, but a special environment is required for most adolescents and adults to attain this stage.* [Italics added for emphasis]

The correctness of the assertion that 30 percent to 35 percent of adults attain the cognitive development stage of formal operations certainly depends on how one defines and measures formal operations. One can find peer-reviewed papers assert that only about half of college students are at the level of formal operations, while other papers that assert that a much higher percentage of college students are at formal operations level. Moreover, a person may be at a formal operations level in one discipline area but not in another.

Thus, for example, a significant percentage of students taking a college algebra course have not yet achieved a level of formal operations in mathematics, even though they may have achieved that level in other components of cognitive development. When such students face the highly symbolic, logical, and abstract aspects of college algebra, their main recourse is rote memorization. This helps explain why so many students do not succeed in this course. The rote memorization approach does not help much in moving students toward achieving a formal operations cognitive level in mathematics.

From your specific point of view, it is important for you to know whether you have achieved formal operations in general, and whether you have achieved formal operations in specific disciplines that you are studying. You may well be able to self-assess, and make a relatively good guess at your level of a Piagetian developmental scale. If you find it necessary to use the *memorize and regurgitate* approach with little understanding, there is a good chance you are not at formal operations in the discipline you are studying.

I have spent quite a bit of time searching the Web for high quality, free, self-assessment Piagetian cognitive developmental instruments, both in general and in specific disciplines. I have not found instruments. However, the next section contains cognitive developmental scales for Math and for ICT. These may help you in determining your current level of cognitive development in these two areas.

Math and ICT Cognitive Development Scales

Figure 6-2 represents my current thinking on a six-level Piagetian-type scale for mathematics. It is an amalgamation and extension of ideas of Piaget and other researchers. Math is a deep discipline, with higher level content and ways of solving problems built upon lower level math. Notice that this discipline-specific scale has two additional levels above the traditional top level of formal operations on the Piagetian scale.

Stage Name	Math Cognitive Developments
Level 1. Piagetian and Math sensorimotor.	Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. Research on very young infants suggests some innate ability to deal with small quantities such as 1, 2, and 3. As infants gain crawling or walking mobility, they can display innate spatial sense. For example, they can move to a target along a path requiring moving around obstacles, and can find their way back to a parent after having taken a turn into a room where they can no longer see the parent.
Level 2. Piagetian and Math preoperational.	During the preoperational stage, children begin to use symbols, such as speech. They respond to objects and events according to how they appear to be. The children are making rapid progress in receptive and generative oral language. They accommodate to the language environments (including math as a language) they spend a lot of time in, so can easily become bilingual or trilingual in such environments. During the preoperational stage, children learn some folk math and begin to develop an understanding of number line. They learn number words and to name the number of objects in a collection and how to count them, with the answer being the last number used in this counting process.

	A majority of children discover or learn "counting on" and counting on from the larger quantity as a way to speed up counting of two or more sets of objects. Children gain increasing proficiency (speed, correctness, and understanding) in such counting activities. In terms of nature and nurture in mathematical development, both are of considerable importance during the preoperational stage.
Level 3. Piagetian and Math concrete operations.	During the concrete operations stage, children begin to think logically. In this stage, which is characterized by 7 types of conservation: number, length, liquid, mass, weight, area, volume, intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking develops (mental actions that are reversible). While concrete objects are an important aspect of learning during this stage, children also begin to learn from words, language, and pictures/video, learning about objects that are not concretely available to them. For the average child, the time span of concrete operations is approximately the time span of elementary school (grades 1-5 or 1-6). During this time, learning math is somewhat linked to having previously developed some knowledge of math words (such as counting numbers) and concepts. However, the level of abstraction in the written and oral math language quickly surpasses a student's previous math experience. That is, math learning tends to proceed in an environment in which the new content materials and ideas are not strongly rooted in verbal, concrete, mental images and understanding of somewhat similar ideas that have already been acquired. There is a substantial difference between developing general ideas and understanding of conservation of number, length, liquid, mass, weight, area, and volume, and learning the mathematics that corresponds to this. These tend to be relatively deep and abstract topics, although they can be taught in very concrete manners.
Level 4. Piagetian and Math formal operations.	Thought begins to be systematic and abstract. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts, problem solving, and gaining and using higher-order knowledge and skills. Math maturity supports the understanding of and proficiency in math at the level of a high school math curriculum. Beginnings of understanding of math-type arguments and proof. Piagetian and Math formal operations includes being able to recognize math aspects of problem situations in both math and non-math disciplines, convert these aspects into math problems (math modeling), and solve the resulting math problems if they are within the range of the math that one has studied. Such transfer of learning is a core aspect of Level 4.
Level 5. Abstract mathematical operations.	Mathematical content proficiency and maturity at the level of contemporary math texts used at the senior undergraduate level in strong programs, or first year graduate level in less strong programs. Good ability to learn math through some combination of reading required texts and other math literature, listening to lectures, participating in class discussions, studying on your own, studying in groups, and so on. Solve relatively high level math problems posed by others (such as in the text books and course assignments). Pose and solve problems at the level of one's math reading skills and knowledge. Follow the logic and arguments in mathematical proofs. Fill in details of proofs when steps are left out in textbooks and other representations of such proofs.
Level 6. Mathematician.	A very high level of mathematical proficiency and maturity. This includes speed, accuracy, and understanding in reading the research literature, writing research literature, and in oral communication (speak, listen) of research-level mathematics. Pose and solve original math problems at the level of contemporary research frontiers.

Figure6-2. Six-stage mathematical cognitive developmental scale.

ICT is a large, vibrant, and rapidly growing field. The International Society for Technology in Education (ISTE) has developed national educational technology standards for students, teachers, and school administrators. These standards have been widely adopted and serve to provide a good sense of direction for the ICT preparation of teachers and their students (ISTE NETS, n.d.).

Following the same line of reasoning that led to the math cognitive development scale given in Figure 6-2, I have been working on a five-stage ICT cognitive development scale. My current version is given in Figure 6-3.

Stage "Title"	Age and/or Education Levels	Brief Discussion
Stage 1. Piagetian Sensorimotor.	Age birth to 2 years. Informal education provided by parents, and other caregivers.	Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. ICT has brought us a wide range of sound and music-producing, talking, moving, walking, interactive, and developmentally appropriate toys for children in Stage 1. These contribute both to general progress in sensory motor growth and to becoming acquainted with an ICT environment.
Stage 2. ICT Preoperational.	Age 2 to 7 years. Includes both informal education and increasingly formal education in preschool, kindergarten, and first grade.	During the Piagetian Preoperational stage, children begin to use symbols, such as speech. They respond to objects and events according to how they appear to be. They accommodate to the language environments they spend a lot of time in. ICT provides a type of symbols and symbol sets that are different from the speech, gestures, and other symbol sets that have traditionally been available. TV and interactive ICT-based games and edutainment are a significant environmental component of many children during Stage 2. During this stage, children can develop considerable speed and accuracy in using a mouse, touch pad, and touch screen to interact and problem solve in a 3-dimensional multimedia environment displayed on a 2-dimensional screen.
Stage 3. ICT Concrete Operations.	Age 7 to 11 years. Includes informal education and steadily increasing importance of formal education at grades 2-5 in elementary school.	During the Piagetian Concrete Operations stage, children begin to think logically. In this stage intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking (mental actions that are reversible) develops. ISTE has established NETS-Student that includes a statement of what students should be able to do by the end of the fifth grade. During the ICT Concrete Operations stage children: • Learn to use a variety of software tools such as those listed in the 5th grade ISTE NETS-Student, and begin to understand some of the capabilities and limitations of these tools. (They do logical and systematic manipulation of symbols in a computer environment.) • Learn to apply these software tools at a Piagetian Concrete Operations level as an aid to solving a wide range of general curriculum-appropriate problems and tasks.
Stage 4. ICT Formal Operations.	Age 11 and beyond. This is an open ended developmental stage, continuing well into adulthood. Requires ICT knowledge, skills, speed, and understanding of topics in ISTE NETS for students finishing the 12th grade.	During the Piagetian Formal Operations stage, thought begins to be systematic and abstract. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. Formal Operations in ICT includes functioning at a Piagetian Formal Operations level in specific ICT-related activities such as: 1. Communicate accurately, fluently, and with good understanding using the vocabulary, notation, and content of ISTE NETS-S for the 12th grade. 2. Given a piece of software and a computer, install and run the software, learn to use the software, explain and demonstrate some of the uses of the software, save a document you have created, and later return to make further use of your saved document. 3. Problem solve at the level of detecting and debugging hardware and software problems that occur in routine use of ICT hardware and software. 4. Convert (represent, model, pose) real world problems from non-ICT disciplines into ICT problems, and then solve these problems. 5. Routinely and comfortably use ICT in the other disciplines you have

		studied, at a level consistent with and supportive of your cognitive developmental level in these disciplines.
Stage 5. ICT Abstract Operations	This is based on informal and formal education well above the high school level.	ICT content proficiency and maturity in contemporary uses of ICT at the undergraduate college level. Full integration of ICT as content, tool, and aid to learning in the courses one has studied up through a bachelor's degree. Within these discipline areas, using ICT to represent and solve problems at the level of the discipline-specific courses one has taken. Learning new ICT hardware and software on one's own.

Figure 6-3 ICT cognitive development and expertise scale.

Constructivism

The thinking activities in the previous section are based on a learning theory called *constructivism*. This theory posits that each learner builds knowledge (learns) by building upon his or her current knowledge.

Learning is a process of building neural connections that tie in with one's current neural connections. Thus, one way to think about constructing new knowledge is to think in terms of growing new neural connections and strengthening current neural connections. However, the ideas of constructivism predate these current insights into brain science. It has long been recognized that new learning is built upon previously learned knowledge and skills. A poor education at any point along the path is a handicap to future learning. Thus, it behooves you to identify important deficiencies in your education and to spend time correcting these deficiencies

When you encountered the word *discipline* early in this book, your brain likely retrieved several possible meanings. As a child, likely your parents and other caregivers disciplined you. You may take a disciplined approach to certain activities in your life. You are working to develop your level of expertise in various disciplines. You selected an appropriate definition to fit with the context of the paragraph you were reading.

Later in your reading you came to a section that provided considerable more information that I find useful in relating the ideas of an academic discipline to ideas of problem solving and gaining expertise. You broadened your insights into academic discipline—you constructed new knowledge based on your current knowledge. You increased your ability to communicate with others and with the accumulated human knowledge about this topic.

When you encounter a new word or idea when reading an academic text, think in terms of what you need to learn to communicate with other people and with the collected knowledge of humans (for example, libraries), and what you need to learn to make effective use of the word or idea in your own personal life. Work to construct meaning that will serve you in communication and information retrieval, and that will serve you personally now and in the future. Work to build a rich vocabulary that is tied in with your overall knowledge, skills, and life experiences.

Situated Learning and Transfer of Learning

There is a substantial amount of research literature on learning theory—how people learn and how to help them learn. From a teacher point of view, learning theories help in the design of curriculum content, instructional processes, and assessment. From a student point of view, an increasing level of expertise in the overall learning process and various applicable learning theories leads to more efficient and effective learning. Both the teacher and student points of view are important to you, as you learn to teach yourself.

Situated Learning Theory

Situated learning is a theory stating that what you learn is highly dependent on the situation in which you learn it. Brown, Collins, and Duguid (1989), in a seminal article on situated learning, discuss the connections between learning and the learning environment.

> Recent investigations of learning, however, challenge this separating of what is learned from how it is learned and used. The activity in which knowledge is developed and deployed, it is now argued, is not separable from or ancillary to learning and cognition. Nor is it neutral. Rather, it is an integral part of what is learned. *Situations might be said to co-produce knowledge through activity. Learning and cognition, it is now possible to argue, are fundamentally situated.* [Italics added for emphasis]

Suppose, for example, that you grow up using the English system of measurements, and learn about the metric system in a math or science class. You then travel to a country where everybody uses the metric system. The chances are you will have considerable difficulty transferring your math and science classroom knowledge of the metric system into dealing with its everyday use during life in another country.

Situated learning theory helps to explain the value of apprenticeship types of education and training. In apprenticeship situations, the learner is engaged in hands-on activities that are closely related to the desired learning outcomes. For example, an apprentice carpenter gets to carry, measure, and saw wood. The apprentice gets to help put pieces of wood together to help form objects such as cabinets and shelving.

In summary, apprenticeships provide good illustrations of effective application of situated learning theory. An apprentice is provided with small-group or one-on-one instruction that is quite specific to the desired learning outcomes. This instruction occurs in a situation where the new learning is immediately used to do productive work. The instruction and the assessment are authentic. In many apprenticeship settings, the apprentice does sufficient work to cover or more than cover the cost of providing the individualized help.

Transfer of Learning

Transfer of learning is one of the most important ideas in education. It involves learning in a manner that facilitates retaining and using one's learning in the future, as well as building future learning upon it. There are various theories about how to teach and how to learn in a manner that facilitates such transfer of learning. Here is a description of transfer of learning from David Perkins and Gavriel Salomon (1992), who provide an excellent, short overview of the field:

> Transfer of learning occurs when learning in one context or with one set of materials impacts on performance in another context or with other related materials. For example, learning to drive a car helps a person later to learn more quickly to drive a truck, learning mathematics prepares students to study physics, learning to get along with one's siblings may prepare one for getting along better with others, and experience playing chess might even make one a better strategic thinker in politics or business. *Transfer is a key concept in education and learning theory because most formal education aspires to transfer.* Usually the context of learning (classrooms, exercise books, tests, simple streamlined tasks) differs markedly from the ultimate contexts of application (in the home, on the job, within complex tasks). *Consequently, the ends of education are not achieved unless transfer occurs.* Transfer is all the more important in that it cannot be taken for granted. *Abundant evidence shows that very often the hoped-for transfer from learning experiences does not occur.* [Italics added for emphasis]

For many years, the prevailing theory of transfer of learning was quite simple. The actual transfer was called either *near transfer* or *far transfer*. In near transfer, one applied his or her learning to contexts and situations that were closely related to (near) the context and situation of the learning. In far transfer, the application was to contexts and situations that were rather different (far from) the learning context and situation. It was also common to first define near transfer and then define any learning that did not readily transfer as far transfer.

Perkins and Solomon (1992) describe this process further:

> Near transfer refers to transfer between very similar contexts, as for instance when students taking an exam face a mix of problems of the same kinds that they have practiced separately in their homework, or when a garage mechanic repairs an engine in a new model of car, but with a design much the same as in prior models. Far transfer refers to transfer between contexts that, on appearance, seem remote and alien to one another. For instance, a chess player might apply basic strategic principles such as "take control of the center'" to investment practices, politics, or military campaigns. *It should be noted that "near" and "far" are intuitive notions that resist precise codification. They are useful in broadly characterizing some aspects of transfer but do not imply any strictly defined metric of "closeness."* [Italics added for emphasis]

The low-road/high-road theory of transfer of learning developed by Perkins and Solomon (1992) has proven quite useful in designing curriculum and instruction. In low-road transfer, one learns some facts and procedures to automaticity, somewhat in a stimulus-response manner. When a particular stimulus (a particular situation) is presented, the prior learning is evoked and used. The human brain is very good at this type of learning.

High-road transfer is based on learning some general-purpose strategies and applying them in a reflective manner. It focuses on critical thinking and understanding. Here is an example. When faced by a complex problem, try the strategy of breaking the complex problem into a number of smaller, less complex problems. This is called the divide-and-conquer strategy. If the resulting problems are simple enough, you may well be able to solve each of them by drawing upon your repertoire of memorized facts and procedures.

Here is a strategy for learning for high-road transfer of learning. When you encounter a new strategy within a course:

1. Identify the generalizable strategy that is being illustrated and used in a particular problem-solving or higher-order thinking situation.

2. Give the strategy a name that is both descriptive and easily remembered. (The divide and conquer strategy listed above is a good example.)

3. Identify a number of different examples in other disciplines and situations in which this named strategy is applicable. Practice using the strategy in these various situations.

An appendix in my book *Introduction to using games in education* contains a large number of problem-solving strategies that are applicable over a wide range of problems (Moursund, 2006). The book illustrates high-road transfer of many of these strategies in the context of games and game playing.

Study Skills and Learning Styles

There has been a considerable amount of research to identify effective study skills and to help students learn to make effective use of their preferred learning styles.

Study Skills

Let's begin with study skills. Undoubtedly you have developed personal strategies for when and how to study. You may have developed some techniques that help you to memorize a list—such as a list of names, a list of dates, or a list of spelling words and their definitions. However, there is a good chance that what you have discovered on your own does not adequately reflect the research on effective practices.

I recently used the search term *"study skills"* in a Google search, and got well over a million hits. When I selected one that looked like it might be interesting, I was pleasantly surprised with what I found (Virginia tech, n.d.). The site includes five short, free online study skills workshops. These are example of DL and CAL. It also contains discussions on 19 topics such as:

- Where does time go? [Self-assessment]
- Study skill checklist [Self-assessment]
- Control of the study environment
- Note taking—the Cornell System
- Writing papers

Websites such as the one mentioned above tend to be rather general purpose. They do not focus on what is known about studying and leaning in a specific discipline such as history, math, or music. Clearly, there are significant differences in effective ways of studying math versus effective ways of studying music. For example, do a Google search on *"study skills" math* and on *"study skills" music*. Look at a few of the hits that seem relevant to you, and compare what is the same and what is different in effective study skills for these two different disciplines.

Many colleges and universities offer instruction on study skills. It may be worthwhile to take such a workshop or short course—if nothing else, than just to see what you know versus what the course designers and instructors think you should know.

After you do some reading and thinking about your study skills, you might want to ask a study skills question in each course you are taking. Ask the teacher what are some of the best research-based studying and learning methods in the specific discipline or course you are taking. If the teacher asks you to be more specific, ask about note taking or some other specific topic that is giving you trouble.

Note Taking

Taking notes during a class, making notes while reading materials for a class, and reviewing one's notes has long been an important contribution to learning. There is a significant amount of research literature on note taking—the value of note taking, how to take notes, and how to use one's notes. For example, quoting from DeZure and Deerman (2001):

> Research on note taking indicates that taking notes in class and reviewing those notes (either in class or afterward) have a positive impact on student learning. Not surprisingly, the preponderance of studies confirms that students recall more lecture material if they record it in their notes (Bligh, 2000). Students who take notes score higher on both immediate and delayed tests of recall and synthesis than students who do not take notes (Kiewra et al., 1991). Moreover, the more students record, the more they remember and the better they perform on exams (Johnstone & Su, 1994). *In summary, note taking facilitates both recall of factual material and the synthesis and application*

of new knowledge, particularly when notes are reviewed prior to exams. [Italics added for emphasis]

There are a variety of ways to take notes. Perhaps you have not had formal instruction in effective note taking. If so, then the following quote from Prentice Hall (n.d.) should be of interest to you

> While almost all students in American education have been taught to take notes in outline form, recently it has been discovered this is not the most successful way to learn from notes. Learning information in a linear format is time-consuming and often highly unproductive. *When you study, your overriding and primary goal should be to understand relationships between and among the topics and supporting detail. Thus, you need to employ a note taking system that helps you understand relationships.* There are, in fact, a few different types of note-taking strategies you should use to record notes. We suggest four major strategies: maps, matrices, diagrams and cards. These strategies will help you identify important relationships among topics and supporting details. [Italics added for emphasis]

Learning Styles

My recent Google search of the quoted expression *"learning style"* produced over a million hits. The search identified many different Websites where students can take free tests to help determine their preferred learning style or styles.

Probably you know about the idea of aural, visual, and kinesthetic learning styles.

- Visual learners learn through seeing.
- Auditory learners learn through listening.
- Tactile/kinesthetic learners learn through moving, doing, and touching.

It may well be that you learn better and faster in one of these learning styles than in the others. If so, try to take advantage of this in designing how you use your studying time.

Frank Coffield et al. (2004) offer a free report that analyzes 13 different learning styles from a teaching-and-learning point of view. The focus in this report is on students in "post-16" education in England, that is, students in educational programs designed for students over 16 years of age.

One of the 13 learning styles highlighted in the report is the Dunn and Dunn learning style instrument, which is described by Thompson and Mascazine (2003):

> The model of learning styles created by Dunn, Dunn & Price (1979, 1980, 1990) comprises five major categories called stimuli. Within these five major categories are 21 different elements that influence our learning. Following are the five types of stimuli and the elements they comprise:
>
>   * Environmental includes: light, sound, temperature, and room design.
>   * Emotional includes: structured planning, persistence, motivation, and responsibility.
>   * Sociological includes: pairs, peers, adults, self, group, and varied.
>   * Physical includes: perceptual strengths, mobility, intake, and time of day.
>   * Psychological includes: global/analytic, impulsive/ reflective, and right- or left-brain dominance.

Thus, if you want to delve into your personal learning styles more deeply, you will want to explore in some detail how each of these five categories of stimuli affect your learning.

Finally, consider the following quote, again from Thompson and Mascazine (2003):

> *But perhaps the greatest benefit from attending to learning styles in mathematics or science education is that of placing more responsibility for learning on the students themselves.* Students

who discover and understand their personal learning styles can and often do apply such information with great success and enthusiasm. (Griggs, 1991) Thus, attending to learning styles can be an ongoing consideration and aid in attacking new or difficult learning situations and the processing of information.

… And while many elements of individual learning styles may be obvious to educators, students may not be aware or appreciative of them. *Thus it is important for educators to help individual students discover, utilize, and appreciate their own unique learning styles.* [Italics added for emphasis]

The point is you have your own unique learning styles. They differ from subject to subject. In addition, they may also differ over time. Through study and practice, you can become a more efficient and effective learner.

Reading Speed and Comprehension

Do you know answers to the following questions?

- How fast do you read in different subject areas?

- What is your level of comprehension when your are reading in different subject areas?

- What is your online reading speed as compared to your off line (reading from hardcopy) reading speed?

Many Websites can help you determine your general reading speed and level of comprehension. I enjoyed the site ReadingSoft.com (2000). This site indicates that on average, people read about 25% slower from a computer screen than when reading hardcopy from good quality paper. I also enjoyed the self-assessment at https://rocketreader.com/cgi-bin/portal/fun_tests/perception.

There are a lot of Websites that focus on speed-reading. Many claim that you can increase both your speed and comprehension. Quoting from the Wikipedia:

Speed reading is a collection of methods of reading which attempt to attain higher rates of reading without unacceptable reduction of comprehension or retention. Such methods include using various psychological techniques such as chunking and eliminating subvocalization.

Some reading research has indicated that instructing a group or class of readers to speed up their reading rate will increase reading comprehension to a limited degree. … However, this is only true to up to a point. When reading rate is increased to beyond the reading for comprehension rate (over approximately 400 wpm), comprehension will drop to an unacceptable level (below 50% comprehension) as measured on standardized reading tests (Cunningham et al 1990).

I wonder if the "below 50% comprehension" statement in the above quotation bothers you. If I am reading a mystery novel and have such a low comprehension level, I will likely have less fun reading the book and I may well not be able to figure out "who done it." If I am reading a college textbook and have less than a 50% comprehension rate, I suspect that I am going to have a hard time passing the course.

These speed and comprehension results are missing ideas from the theory of constructivism. While reading, you construct knowledge by building on what you already know. If you already know a great deal about the topic you are reading, you can skim, looking only for new ideas. This allows a high rate of speed and a high level of comprehension. Indeed, it is likely that you will score quite high on a comprehension test without even reading the material.

If, however, the material contains content that you know relatively little about, then your brain is faced by a very challenging constructivist task. You do not have a strong foundation to build upon, and you do not have a good basis for picking out the new, important ideas. In this situation, you will likely need to read at a very slow rate and spend a lot of time reflecting and rereading in order to achieve a reasonable level of comprehension. The important message is that you should adjust your reading speed to fit the particular discipline you are studying and to fit the amount of new information you are encountering.

Learning More About Yourself

There are a huge number of different self-assessment tests available on the Web However, as Albert Einstein said, "Not everything that can be counted counts, and not everything that counts can be counted." Here are some examples of some things that can be counted (measured):

- A Google search of the unquoted expression *free self-assessment test* produced more than a million hits.

- A Google search of *"free IQ test"* and produced over 3 million hits. I found a reasonable level of consistency in my personal results from several of these tests. See, for example, http://giqtest.com/html/giqtestStart.html.

- A Google search of *"free Emotional Intelligence test"* produced well over a million hits. For example, see http://www.ihhp.com/testsite.htm.

- A Google search on *"free personality test"* produced more than 300,000 hits.

- A Google search on "free career test" produced well over a million hits.

Summary and Self-Assessment

There has been substantial research in learning and learning theory. Some of this research is important to curriculum developers and teachers. It is also important to students.

One of your goals should be to learn about yourself as a learner. Learn your relative strengths and weaknesses. Learn to take advantage of your strengths, and work to overcome your weaknesses.

Another of your goals should be to get better at being your own teacher and in helping others to learn. Spend some time thinking about when and how you help others learn. Assess your skills in this area.

In each course that you take, figure out what works best for you in learning the material, what is an appropriate reading speed, how to self-assess your progress, and how to learn for transfer of learning. Analyze your current cognitive developmental level within the discipline, and think about what you can be doing to increase your cognitive developmental level.

Think back over some of the important ideas in this chapter. Select one that seems particularly important to you. Then analyze it from the point of view of your current level of ICT knowledge and skills.

Chapter 7

Increasing Your Expertise in ICT

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

"I hear and I forget. I see and I remember. I do and I understand." (Confucius)

 "In their capacity as a tool, computers will be but a ripple on the surface of our culture. In their capacity as intellectual challenge, they are without precedent in the cultural history of mankind. " (Edsgar W. Dijkstra)

ICT is a huge and rapidly growing field. Some students plan their higher education and their work experiences with a goal in mind of building and maintaining a high level of expertise in this area.

Many students tend to see ICT as a possibly useful means to an end, but their end goals may be far removed from being an expert in ICT. They may be quite content to develop some ICT islands of expertise that serve their particular needs.

This chapter explores various topics in ICT from the point of view of achieving personal and professionally useful levels of expertise. Reread the quote from Edsgar W. Dijkstra given above. Dijkstra was a Dutch computer scientist who made many important contributions to the development of the discipline of Computer and Information Science.

Some Pervasive ICT Uses in Higher Education

Essentially all college students and faculty routinely use ICT. It is now common practice for a college or university to assign all new students an email account and to assume that they know how to use email. It is now commonly expected that all students know how to use a word processor, how to access the Web, and how to use a search engine to locate information on the Web.

All of these activities (and more) are at or below the fifth grade standards created by the International Society for Technology in Education (ISTE NETS, n.d.). I recommend that you read these precollege standards, so that you can see what college faculty might assume you know, and so that you can (if necessary) remediate some of the holes in your precollege ICT education. As an example, here are four of the items in the fifth grade standards:

1. Use general-purpose productivity tools and peripherals to support personal productivity, remediate skill deficits, and facilitate learning throughout the curriculum.

2. Use technology tools (e.g., multimedia authoring, presentation, Web tools, digital cameras, scanners) for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.

3. Use telecommunications efficiently to access remote information, communicate with others in support of direct and independent learning, and pursue personal interests.

4. Use telecommunications and online resources (e.g., e-mail, online discussions, Web environments) to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.

Thus, for example, many higher education faculty members feel free to tell their students to contact them and their fellow students by email, and they do not hesitate to require an assignment to be word-processed and turned in as an attachment to an email message. Faculty members do not expect to have to use class time to teach grade school level uses of ICT.

Course and Learning Management Systems

It is now common for higher education institutions to provide a learning management system or a course management system for use by their faculty and students. Here, I will use the term learning management system (LMS) to refer to both. An LMS is designed to help students learn and faculty teach. As noted in Wikipedia:

> A Learning Management System (or LMS) is a software package that enables the management and delivery of online content to learners. Most LMSs are web-based to facilitate "anytime, any place, any pace" access to learning content and administration.

> Typically an LMS allows for learner registration, delivery of learning activities, and learner assessment in an online environment. More comprehensive LMSs often include tools such as competency management, skills-gap analysis, succession planning, certifications, and resource allocation (venues, rooms, textbooks, instructors, etc.).

As a student, you are used to participating in small group or whole class discussions. It may well be that you do far more or far less than your fair share of the talking. Relatively few faculty members make an actual count of the number of contributions you make to the discussions or make a written note on the quality of your contributions.

Now, consider participating in online discussions where the input mode is keyboarding or voice. In this setting, it may well be that part of your grade depends on the number and quality of your contributions to the discussion. It is relatively easy for a faculty member to monitor online discussions.

A typical LMS includes electronic gradebook software. This helps a faculty member to provide easily accessible and up to date information on student performance on assignments and tests. Research suggests that student receiving high quality and timely feedback of this sort learn more than those who don't.

So, if you are in a course where such online feedback would be useful to you but is not being provided, you might ask the faculty member if this service could be provided. There is a deeper underlying theme in this suggestion. Many faculty members are being slow to learn about roles of ICT within the disciplines they teach. They are not being forward-looking in integrating ICT-

related aspects of their disciplines into the courses they teach. Students can help change this situation.

An LMS typically includes provisions for online testing. That opens up a new can of worms for faculty members and students. Should online tests be used just for the purposes of student self-assessment, or should they use them for grading? If used for grading, how does one prevent cheating?

Learning a New Piece of Computer Software

There are tens of thousands of different pieces of computer software. They vary considerably in cost (free to quite expensive), computer operating systems they run under, quality (terrible to quite good), ease of use, and ease of learning to use.

In the very early days of electronic digital computers, almost every computer user was a computer programmer. It took considerable effort to gain a useful level of expertise in representing and solving problems. That has changed substantially over the years.

Modern commercially successful software is designed to make it relatively easy for a beginning user to get started, experience some success, and move into a learn-by-doing mode. That is, a user can quickly gain a personally useful level of expertise and a start along the path of gaining increased expertise by reading the instruction manual, making use of the Help features built into the software, and by hands on (often trial and error) experience. Many pieces of software include a tutorial mode—computer-assisted learning that helps the user learn to get started.

Once you get started in using a new piece of software, there is a good chance you can provide feedback to yourself on how well you are doing. Often you will encounter difficulties or it will occur to you that "there has got to be a better way." Some standard ways to deal with such difficulties include:

- Make use of the mini-tutorials that are built into the software system.

- Experiment. Use trial and error. Remember, however, that if you are working with a document that you have created, make a backup copy before you do something that may damage your document.

- Use the Help features. Some built-in help has a modest level of artificial intelligence and can provide help in the context of the problem you are currently encountering. You can expect that this type of help will become more common and quite a bit better in the future.

- Read a relevant part of the manual. Nowadays, the manual is usually not available in hard copy. Rather, it is part of the software package and is accessed online.

- Seek help from a colleague. Such one-on-one help (individual tutoring) is an excellent aid to learning. One of your goals should be to develop a reasonable level of expertise in both receiving and giving such tutorial aid.

- Take a workshop or a short course

Since you are already a computer user, you have some level of expertise in the above activities. You should develop computer-use habits that will help increase this expertise. For example, suppose you encounter a difficulty when using a particular computer system and piece

of software. First, try to figure it out on your own. Reflect on what the problem is and what you know about solving the problem. Experiment with using some trial and error and the built-in help features. Before you ask for help from a human, formulate your question very carefully. While asking for help, clearly state your problem and give a careful statement of what you have tried to do to solve the problem.

Amplification, and Moving Beyond Amplification

Remember what the first steam or gasoline-powered cars looked like? They looked like "horseless" carriages. They are an example of a first-order application of a technology, an amplification level. As is often the case with a new technology, the initial horseless carriages were relatively hard to maintain and use, the needed infrastructure—paved roads and gas stations—was not yet available, and only a relatively few early adopters were venturesome enough to purchase and try out the new-fangled invention. Eventually the technology got a lot better, the infrastructure got a lot better, and cars transformed our society.

Nowadays, essentially every student entering college has developed a personally useful level of knowledge and skill in using a word processor, email, and the Web. The student likely has a number of other ICT-related areas of personal expertise, such as using a cell telephone, digital camera, and video camera; driving a car that contains a number of microcomputers; making use of digital music; and so on. In all of these examples, the ICT is so transparent that the typical user does not think about the underlying ICT or the roles of computers.

These are all examples of amplification-level use of ICT. None get at the depth of ICT capabilities in the various courses you are studying. This is where a combination of bottom up and top down approaches can make a big difference. In some courses, you will encounter faculty members who are near the cutting edge in use of ICT in their research and other scholarly activities. They have moved well beyond the amplification stage in use of ICT, but do not yet bring such ICT use into their courses. You, as a student, want to encourage the teacher to being these ideas into the course you are taking.

Alternatively, you may find that you and some of your fellow students know some things about ICT that should be in the course. You should bring these ideas to the attention of both the teacher and the other students in the class. Work to create a situation in which the students and faculty learn together.

Each discipline offers its own challenges. For example, have you ever tried to use a standard word processor to word process mathematics notation? This problem has been addressed by special additions to standard word processor software, and special mathematics word processing software. For example, Microsoft Word includes an Equation Editor that facilitates use of more than 150 math symbols. A Math Department faculty member may be familiar with such software. Perhaps you should be learning a little bit about it in a math class?

A second example is provided by information retrieval. As noted earlier in this book, one of the most important aspects of problem solving is learning to make effective use of the previous work of others. This means that an important part of learning any discipline is learning to retrieve, understand, and make use of the stored information of the discipline. Thus, every course could (in my opinion, should) include explicit instruction in how to locate, retrieve, understand, and use important aspects of the accumulated knowledge of the discipline.

Here are some other aspects of information retrieval. Suppose that a couple of years after taking a course, you decide you need to relearn key ideas from your course. Where will you find information about these ideas and aids to learning them? What are the key Web search engine search terms and search ideas to use in finding a good Website? Are there long-lasting Websites that you could have learned how to use when taking the course? Are there computer programs that can solve or help solve some of the important problems discussed in the course? Where can one find the new ides that are being developed and are relevant to the course?

Word Processing and Desktop Publication

This section uses word processing to help illustrate moving beyond amplification. It is estimated that a typical user of a full feature word processor such as Microsoft Word only makes use of about three to five percent of the capabilities of the software. A word processor provides an excellent example where it is easy to achieve a personally useful, amplification level of knowledge and skill.

Chances are that by the time you first began to learn to use a word processor you already had learned to read and write. You were experienced in detecting and correcting errors in your writing. You had developed skills as a copy editor of your own work. All of this previous learning was available to you as you learned the rudiments of writing and editing using a word processor. The following personal story illustrates this situation.

One evening many years ago, my younger daughter who was a high school sophomore came to me and asked if I would teach her how to use a computer. She had a written report that was due the next day, and she believed that it would be helpful to write it using a word processor. (Notice that she brought with here knowledge that her parent used a word processor and that they had talked about how useful this was.)

Aha! A teachable moment. She was a good typist—I had required all of my children to take a typing course. With about two minutes of instruction, she was started. There is considerable transfer of learning from a typewrite environment to a word processor environment. Correcting keyboarding errors and making small edits to a sentence are very easy to learn to do in a word-processing environment.

Perhaps a half hour later she asked if there was an easier way to get back to earlier parts of the document than just repeated back spacing. (This computer system did not have a mouse.) Aha, another teachable moment. Still later came the question of how to save and to print out the completed document.

Even for a long-winded professor like me, the total amount of instruction time was less than ten minutes, and my daughter was pleased by the results. She had developed a personally useful level of expertise in word processing. In essence, she had learned to use a computer as a typewriter with some added features.

Moving Beyond Using a Computer as a Typewriter

Even a rudimentary level of knowledge and skill in using a word processor is valuable to a student—even a student who uses a hunt-and-peck approach to keyboarding. However, a word processor is a quite powerful tool, and it takes considerable effort to gain a reasonable level of expertise in using this tool.

A student can learn fast keyboarding, and a student can learn to use some additional features of a word processor. Since touch typing has been a school subject for many years, there is a lot known about how long it takes an average person to achieve a level of automaticity that does not decline rapidly when not being used. For example, a typical fourth- or fifth-grade elementary school student can learn to type (or keyboard) about twice as fast as hand printing or handwriting. It takes perhaps 30 to 40 hours to gain a speed of 25 or more words per minute.

Typing classes in middle school or high school used to be a half-year or a full year in length. The longer courses tended to stress skills related to becoming a professional secretary or typist. For example, how do you center a heading when using a typewriter? It is much easier to learn and easier to do using a word processor.

A word processor provides different fonts, and these in turn allow for different type sizes, italics, and boldface. All of these are easy to learn to use, and they are all beyond the capabilities of a typical typewriter.

There are many other word processor features that are not available on a typewriter. I find the spelling checker and the grammar checker to be quite useful. I also find it quite useful to have the computer system automatically finds and correct some of my common typos. As an example, my fingers frequently keyboard the word *education* with the i and o interchanged. When I noted that was happening, I merely instructed my word processor to automatically correct this error, without even bothering to bring the error to my attention.

As another example, look back at the tables used discussing cognitive development theory in Chapter 6. Do you know how to create such tables using a word processor? Look at the References near the end of the book. The layout was done by making use of a hanging indent—a type of indent feature easily implemented in a modern word processor. The alphabetization of the list was done using an alphabetical sorting feature built into the word processor.

Desktop Publication

The microcomputer-based word processor blossomed into a transformational technology when sophisticated desktop-publication software and a relatively inexpensive laser printer became available in 1984. The linotype that had been a mainstay in publishing for nearly a hundred years was doomed. The combination of microcomputer, desktop publication software (even a good word processor sufficed), and the laser printer completely transformed an industry. Some of the areas of expertise of a linotype operator were no longer useful.

Historically, the overall publication process used to involve content editors, copy editors, and layout designers. Many people acquired the hardware and software to do desktop publication without thinking much about these other areas of expertise required to produce high-quality products. I have learned to do some of these tasks at a modest level. Thus, most of my current books are being published without the benefits (and cost) of professional content editors, copy editors, and layout designers.

I have not included any pictures in this particular book, but I have included a number of graphic diagrams that I created using computer graphics software. A modern word processor makes it quite easy to add pictures and diagrams to a text. However, the word processor does not know if these pictures and graphics help to communicate the intended message and are a useful part of the content. The human writer provides this type of intelligent insight.

Notice that this book has a table of contents and an index. While writing the book, I highlighted various heading and told the word processor that these were to be Table of Contents entries. Similarly, I highlighted various words and phrases and told the word processor that these were to be in the Index. In both cases, most of the rest of the work was done automatically. On a book of this length, the computer can read through the entire text, select all of the terms that I have specified to go into the Index, alphabetize them, attach the appropriate page numbers, and add the results to the book in just a few seconds. Later, as I am editing the book, perhaps moving large blocks of text and adding more index entries, the re-indexing process takes only a few seconds.

It is helpful to keep this example of word processing versus desktop publishing in mind as you explore other computer applications. Typically, a new computer hardware or software tool is developed to help solve some problem or accomplish some task where there is considerable demand for "a better way." Often the computer system is powerful enough so that it can empower a novice with just a little training to accomplish tasks that previously required many hundreds of hours of training and experience.

However, professional level use of such software typically requires considerable education and/or training. A big part of the education and training focuses on learning the discipline within which the tool is being used. Another big part focuses on things that humans can learn to do much better than computers.

For example, even the best of modern computer-based spelling checkers are not as good as a good human spelling checker. The best of computer-based grammar checkers are not nearly as good as a good human copy editor. We are a very long way from having computer systems that are good at content editing. Being good at using a word processor may help you to write more and to edit your writing more carefully. However, a word processor does not make a good writer out of a poor writer.

Email

Email is another productivity tool that is easy to learn to use at an amplification level. For a person who can read and write, a few minutes of instruction and practice allow one to send and receive email messages. Compare this with the time and effort it took telegraph operators a little over 160 year ago to learn Morse code and use the telegraph system.

However, there is much more to learn about email. How does one organize, save, and later retrieve message one has received? How does one avoid getting unwanted ads and other spam? How does one deal with email lists? For example, how does one avoid responding to the whole list when one wants to respond just to one person? How does one create a mailing list? How does one include pictures and graphics in an email message? How does one send and retrieve attachments? How does one add an automatic signature to one's messages being sent? It is not so easy to learn to use the various additional features and to use them wisely.

It has been a very long time since I have written and sent a hand written letter. During this time, I have written some letters using a word processor and sent them by surface mail or as email attachments. I find this useful because I give careful thought to what I am writing and I do a careful edit of the results. In addition, the letter goes out with a personal hand written signature at the end.

Most of my email messages are composed in an email system, perhaps very briefly edited, and then sent. They often contain typos. However, I have not adopted writing techniques such as using only lowercase letters, abbreviating many words, and not paying much attention to "good" grammar and spelling. Now and in the future you will need to decide for yourself how you want to present yourself in email messages and in other forms of written communication.

Here is a hard question: When should one use email in communication, and when is this a bad idea?

One way to answer this question is to think about other modes of communication. For example, consider a telephone voice or video conversation. If you are good at "reading" voice expression, you get information that is not available in an email conversation. If the video is of sufficient quality, you can pick up some of the body language.

In a face-to-face conversation, you can "read" the facial expressions and other body language of the person you are talking to. You get feedback from this body language, and you get feedback from the content and emotions in the voice responses of the person you are conversing with. All of this is missing in an email message or sequence of interchanges of email messages.

Thus, you now have three commonly used modes of human-to-human communication: email and chat groups, telephone (voice or video phone), and face-to-face. Each has advantages and disadvantages. You can take a trial and error approach to learning about when and when not to use each of these modes of communication. Through your use of these three modes of communication, you have developed some level of expertise in the advantages and disadvantages of each.

Spreadsheet

An entry in Wikipedia describes the development of VisiCalc, a 1979 spreadsheet program:

> Dan Bricklin has spoken of watching his university professor create a table of calculation results on a blackboard. When the professor found an error, he had to tediously erase and rewrite a number of sequential entries in the table, triggering Bricklin to think that he could replicate the process on a computer, using the blackboard as the model to view results of underlying formulas. His idea became VisiCalc, the first application that turned the personal computer from a hobby for computer enthusiasts into a business tool.

> VisiCalc went on to become the first "killer app," an application that was so compelling, people would buy a particular computer just to own it. In this case the computer was the Apple II, and VisiCalc was no small part in that machine's success.

Most of the first people to learn to use spreadsheet software already knew quite a bit about bookkeeping or accounting. Thus, it was relatively easy for them to learn to create simple spreadsheets. However, over time, spreadsheet software grew much more powerful and many people with no business background found it useful to learn to use the software. Often they had to deal with business-oriented examples and instruction manuals as they tried to learn to use the software as an aid to solving problems in science and other disciplines.

While it is easy to learn to use spreadsheets developed by others, it is a considerable challenge to learn to design, develop, and test spreadsheets that help to solve challenging problems and accomplish challenging tasks. One can build a career at being a spreadsheet expert.

Over the years, spreadsheet software has come to contain many of the features of a computer programming language. Indeed, a spreadsheet software package may well contain a computer

programming language such as BASIC as one of its features. Excel, Microsoft's spreadsheet program, is exceedingly powerful and exceedingly complex, and it includes BASIC.

One of the key uses of spreadsheet software is spreadsheet modeling and simulation. How does one use a spreadsheet to develop a model of a business operation such as payroll or inventory? One needs to know the business operations and one needs to know how to design, create, test, and debug the relatively complex spreadsheet model and simulation. This means one must have a reasonably high level of expertise in the business areas and in the software. Similar statements hold for developing spreadsheet models in other disciplines.

Applications That Are Inherently Beyond Amplification

There are a number of computer applications that are so powerful that they make it possible for the user to solve problems and accomplish tasks well beyond what can readily been done by hand. A few examples include computer modeling and simulation, statistical packages, computer algebra systems, Geographic Information Systems (GIS), MIDI (music) interface systems, computer-assisted design (CAD) and computer-assisted manufacturing (CAM) systems, and digital audio, photo, and video editing systems.

Each of these provides an example of where an accomplished user can gain a considerable competitive advantage over non-users and novice users. These applications are so powerful that they have significantly changed entire disciplines. For example, consider computer modeling and simulation in the sciences. In 1998, one of the winners of the Nobel Prize in chemistry received the prize for his many years of work in computational chemistry (computer modeling and simulation in chemistry). Computational biology, chemistry, mathematics, and physics are now major components of their respective disciplines.

Here is a personal experience I had with powerful software. More than 15 years ago, I was teaching a computers and mathematics course for preservice and inservice teachers. One day I opened my surface mail and found that I had received a copy of the computer algebra system Mathematica, designed to run on an Apple microcomputer. After a little experimentation, I took the software and my old freshman calculus book to the class meeting later in the day. I first demonstrated that the software could do various impressive calculations, such as exactly calculating 50 factorial. I then began to give the program problems from the end of the book chapters. After seeing success on the easier problems, I began to use the "starred" problems in later chapters. My class and I were "blown away" by what this software could do. In essence, it could solve each of the procedurally oriented problems in the book.

Mathematica is a product of Wolfram Research. Quoting from their company history Website http://www.wolfram.com/products/mathematica/history.html:

> It is often said that the release of Mathematica marked the beginning of modern technical computing. Ever since the 1960s, individual packages had existed for specific numerical, algebraic, graphical, and other tasks. But the visionary concept of Mathematica was to create once and for all a single system that could handle all the various aspects of technical computing—and beyond—in a coherent and unified way. The key intellectual advance that made this possible was the invention of a new kind of symbolic computer language that could for the first time manipulate the very wide range of objects needed to achieve the generality required for technical computing using only a fairly small number of basic primitives.

Over the years, computer algebra software has been greatly improved and microcomputers have become thousands of times more powerful. Quoting from Wikipedia:

> A computer algebra system (CAS) is a software program that facilitates symbolic mathematics. The core functionality of a CAS is manipulation of mathematical expressions in symbolic form.
>
> …
>
> The symbolic manipulations supported typically include:
>
> …
>
> • change of form of expressions: expanding products and powers, rewriting as partial fractions, constraint satisfaction, rewriting trigonometric functions as exponentials, etc.
> • partial and total differentiation
> • partial and full factorization
> • solution of linear and some non-linear equations over various domains
> • solution of some differential and difference equations
> • statistical computation, theorem proving, graphing, etc.

In computer algebra systems and in many other powerful applications, software has been developed that incorporates a significant amount of the accumulated knowledge of one or more disciplines. However, one cannot learn to use the software at a worthwhile level without having substantial knowledge of the discipline. While use of the software can be taught independently of a content course in the discipline, it is highly appropriate to integrate instruction in the software with instruction in the content of the discipline.

Such powerful software is disruptive to traditional coursework in areas where the software is particularly useful. For example, suppose that a person is taking a traditional freshman calculus course in which the existence of computer algebra systems software is not even mentioned. Students will spend a great deal of time learning to do a variety of procedures by hand and by use of math tables that computers can do very rapidly and accurately. The issue is this: Should the course continue to be taught in the traditional fashion or should it be taught with content that effectively merges the traditional content with the capability of the software? Various research projects conducted over the past 20 years have produced strong evidence supporting the merged course. Most mathematics departments have been slow to adopt this change.

Here is a final example of powerful software described in Wikipedia:

> A geographic information system (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, and present the results of all these operations. Geographic information science is the science underlying the applications and systems, taught as a degree program by several universities.
>
> Geographic information system technology can be used for scientific investigations, resource management, asset management, Environmental Impact Assessment, Urban planning, cartography, criminology, sales, marketing, and route planning. For example, a GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, a GIS might be used to find wetlands that need protection from pollution, or a GIS can be used by a company to find new potential customers similar to the ones they already have and project sales due to expanding into that market.

Learning by Doing

One of the weaknesses in much of higher education can be described as *delayed gratification*. There is often a considerable time and place separation between the learning

processes and the application of the learning (other than to pass tests and do homework assignments).

Some faculty members make a significant effort to provide authentic and immediate opportunities for students to use what they are learning. Others seem to feel that the traditional assignments and tests suffice.

You, personally, can contribute to the authenticity of the learning and assessment. In terms of ICT, the approach is simple enough. Whenever it seems useful and appropriate to you to make use of ICT in your studying, deciding what to learn, doing assignments, and so on, consider making use of ICT tools. As you use these tools, reflect on their capabilities, limitations, and applicability to the situation you are using them in.

You can push the envelope. For example, suppose that you are doing a major term project, either individually on as a member of a team. This is an excellent environment to make use of ICT. If you are working on a team, learn to use collaborative software such as a Wiki or a collaborative word processor (Writely, n.d.). Also, perhaps the product produced by the project could be interactive multimedia. Perhaps the end of term inclass presentation could make use of a projection system and multimedia. Ask the teacher if this would be okay.

Summary and Self-Assessment

This chapter illustrates several very important ideas. Here are two of them:

- There are many pieces of software that are inherently interdisciplinary in nature. Often one can gain a personally useful (amplification) level of knowledge and skill in the use of one of these pieces of software in an hour or so. However, you can begin to gain a competitive advantage by learning one or more of these pieces of software at a substantially higher level of expertise.

- There are a number of pieces of software that are so powerful that they have changed entire disciplines and/or helped to create major new components in existing disciplines. GIS provides an excellent example. A student can gain a significant competitive advantage by learning traditional geography or traditional environmental studies and at the same time, acquiring a high level of GIS use in geography or environmental studies.

In these two examples and in many other "powerful software" examples, the underlying idea is that a person and computer system working together can often do much better than either alone. You already know it takes thousands of hours of study and practice to achieve a high level of expertise in a traditional discipline. Thus, it is not a modest request to suggest you spend many hundreds of hours developing a moderately high level of expertise in using each of several powerful pieces of software that are relevant to your specific (non-computer) discipline interests.

This situation of powerful software becoming a critical part of a discipline will continue. This does not mean that traditional disciplines and traditional knowledge and skills in these disciplines will go away. Rather, it means that people who want to excel in such disciplines should give careful consideration to how they balance their coursework and studies between the old and the new.

For self-assessment, think about the various disciplines you have studied or are thinking about studying. Reflect on whether you have gained a beyond-amplification level of knowledge

and skill in using ICT in these various disciplines. Compare your level of ICT knowledge and skills with your fellow students in the disciplines that interest you. Try to determine if you are gaining a competitive advantage.

Chapter 8

Brief Introductions to A number of Key Ideas

"Do not fear going forward slowly; fear only to stand still." (Chinese proverb)

"The value of an idea lies in using it." (Thomas A. Edison)

The earlier chapters of this book have provided general background information helpful in understanding a wide variety of aspects of ICT in your education. This chapter briefly introduces some powerful ideas that can change your life. Each of these topics is worthy of a whole chapter—or indeed, a whole book and more.

For this chapter, I considered organizing the ideas from what I consider most important to less important. The complexity of this task befuddled my mind, so what you see is somewhat of a hodgepodge order. However, as is often said about beauty, importance is in the eye of the beholder. Ultimately the importance of each idea needs to be judged by you, the reader.

As you read these ideas, I hope that one or more of them will catch your attention, and that you will build the idea into a useful personal island of expertise. Remember the words of Thomas Edison, "The value of an idea lies in using it."

Idea 1: Auxiliary Brain

Since the early days of computers, it has been common to refer to such a machine as being an electronic brain. That is because a computer seems to have some brain-like characteristics. I like the idea of thinking about a computer as an auxiliary brain—as a type of prosthesis.

You are used to making use of aids to your physical body. Thus, you may make use of clothing, bicycle, car, airplane, telescope, microscope, and so on. Some of these tools are quite easy to learn to use, while others may requires years of education, training, and experience in order to gain a high level of expertise.

You are also used to making use of aids to your brain. Reading, writing, paper and pencil arithmetic, book, calculator, audio and video storage and playback devices, and computer all fall into this category.

The computer brings a new dimension to physical and mental tools. A computer can be used for the storage and retrieval of information, but it can also be used for the automated processing of information.

Here is an example. You are used to the idea of "telling" a calculator what you want done by a sequence of key strokes, and then the calculator automatically carrying our a computational procedure for you. Somewhat in the sense, merely "telling" a problem to a computer and telling it to solve the problem can solve many problems. Thus, for example you easily learn to tell a computer to graph data, solve equations, and retrieve information. You can easily ask a *Global*

Positioning System (GPS) system you are holding in your hand where it is (where you are) located on the surface of the earth.

Through progress in artificial intelligence, the "telling" process is increasingly being done by voice input. Other forms of input include keyboard, touch screen, and graphics tablet.

But wait…there's more. When you download a music file or a text document to a computer, you are telling your computer to "memorize" what you are downloading. The speed of this memorization process depends on the bandwidth of the connectivity and the computer hardware. With modern technology, a full-length book might be downloaded from a distant computer into your computer in a few seconds. After telling the computer to download a file, you can tell it to play (a music of video) file, display (a file containing text, graphics, and pictures), or read out loud a text file.

Each of you will develop your own insights into the capabilities, limitations, personal uses, and professional uses of computer as an auxiliary brain. Here are a few things to keep in mind:

1. Some aspects of this auxiliary mind are so easy to learn to use and so powerful in use that a great many of your fellow students and peers will become fluent users. Failure to develop fluency in such uses may well lead to a competitive disadvantage in school and on the job.

2. An auxiliary brain can do many things faster and more accurately than you. Moreover, auxiliary brains will get more powerful over time, as thousands of researchers and companies work to improve their capability.

3. Many of the uses of an auxiliary brain can be easily learned at an amplification level—at a personally useful level. However, many others require a substantial amount of learning time and effort to gain a level of expertise that will give you a competitive advantage in solving problems and accomplishing tasks.

4. Unless your professional goals are mainly in the area of ICT expertise (for example, to be a computer technician, computer programmer, etc.), then you are faced by the need to balance your education time and efforts in traditional components of a (non-computer) discipline and computer aspects of the discipline. There is a reasonable chance that some of your faculty members will not be as much help in this endeavor as you would like. Remember, it is your education. It is up to you to shape this education to fit your long term needs and your views of your future.

Protect and Nurture Your Auxiliary Brain

I hope that you wear a seatbelt when riding in a car, and that you wear a helmet when riding a bicycle, motorcycle, or motor scooter. It should be obvious to you that you want to protect your brain and other components of your body.

Now, how about protecting your auxiliary brain and its contents? Suppose that you are carrying your laptop computer in your arms, walking to class and talking to a fellow student. You trip over a bump in the sidewalk, fall, drop your computer, and skin your knee.

The chances are that you can immediately get up, continue walking, later apply some first aid to your knee, and eventually your knee injury will heal.

But, what about your laptop computer and its contents? If you damage some of its components, the computer will be out of service until you can get them repaired or replaced. Suppose that you damage a hard drive. It is possible that some of your files cannot be recover— and file recovery from a damaged hard drive can be very expensive.

Of course, we do not need to present this scenario of tripping and falling. Think of yourself as seated comfortably, enjoying the pleasure of using your computer to browse the Web and chat with friends. All of a sudden, you hear a shrill grinding noise, and your computer dies. Perhaps it was a hard drive crash! Instead of a hard drive crash, consider the possibility that you are merely writing a paper and some sort of software error occurs. Your machine crashes, and the document you are writing is lost.

Equally bad things can happen from computer viruses and other malware. Quoting from the Wikipedia:

> Malware is software designed to infiltrate or damage a computer system without the owner's informed consent. It is a portmanteau of the words "malicious" and "software". The expression is a general term used by computer professionals to mean a variety of forms of hostile, intrusive, or annoying software or program code.
>
> …
>
> Software is considered malware based on the perceived intent of the creator rather than any particular features. It includes computer viruses, worms, trojan horses, spyware, dishonest adware, and other malicious and unwanted software.

Here are some suggestions to help protect your auxiliary brain:

1. Install anti-virus protection, and keep this software up to date. Learn enough about sources of viruses and other malware so that you have a chance of detecting and avoiding them when they arrive as attachments to your email.

2. Some pieces of software include a provision for automatic SAVE of a document at prescribed time intervals. Thus, for example, you might want to set your word processor so that it does a SAVE every five minutes. Keystroke capture and save software is available. It captures ever keystroke you keyboard, and can be used to recover lost material if your computer crashes.

3. Do an off-machine backup of important files every day. You might do this to a flash drive (thumb drive, pen drive), a CD-ROM or DVD-ROM, an external hard drive, or by making use of a variety of off site storage facilities available on the Web.

4. There are a variety of pieces of software (some may come free with your computer system) that can examine your computer files, detect a variety of errors and problems, and correct some linkage and storage errors. Learn how to use such software.

Your college or university probably has a technical support center. Keep a phone number and email address for this center in a convenient location, so that if something goes wrong with your computer you can quickly seek help. This center may have a Website containing suggestions about what to do if something goes wrong and what to do periodically to help maintain the health of your computer system.

For example, as I was editing this chapter a few minutes ago, my cat knocked over a glass of water standing near my keyboard. The water flooded my keyboard. Bad kitty! What should I do? What if it had been a glass of pop or a beer?

Fortunately for me, I had done a backup to a flash drive just before the accident occurred. While my keyboard dries, I am using my laptop computer to continue my editing work.

Idea 2: Procedural and Computational Thinking

Using a computer system involves telling the system what you want it to do. The type of thinking involved in telling a computer what you want it to do is called procedural thinking or computational thinking. The *term computational* thinking is now coming into vogue. It can be considered to be broadening of the idea of procedural thinking.

The term computational thinking is now being used to describe people and computers working together to solve problems and accomplish tasks. As Jeannette Wing (2006), a highly respected computer scientist, says:

> Computational thinking builds on the power and limits of computing processes, whether they are executed by a human or by a machine. Computational methods and models give us the courage to solve problems and design systems that no one of us would be capable of tackling alone. Computational thinking confronts the riddle of machine intelligence: What can humans do better than computers, and what can computers do better than humans? Most fundamentally it addresses the question: What is computable? Today, we know only parts of the answer to such questions.

A computer program is a detailed step set of instructions that can be interpreted and carried out by a computer. A computer is a machine that can quickly and accurately follow (carry out, execute) the detailed step-by-step set of instructions in a computer program. Computer programmers design, write, and test computer programs—so they are deeply involved in doing computational thinking.

However, all computer users are involved in computational thinking at some level, as they interact with a computer and tell it what they want done. This is true whether you are playing a computer game, retrieving information from the Web, or using a word processor to write a paper.

Three "Levels" of Telling a Computer What to Do

You can tell a computer what you want done by using an applications program such as a word processor, by using problem-solving software such as a spreadsheet, or through use of a general purpose programming language.

The discipline of computer and information science (CIS) is large and growing rapidly. It is a complex field, with a number of important sub disciplines. Chapter 4 provides a brief introduction to Artificial Intelligence. This sub discipline of CIS is now more than 50 years old.

The history of computer programming (software engineering) is often traced back Ada Lovelace. Quoting from the Wikipedia:

> Augusta Ada King, Countess of Lovelace (December 10, 1815–November 27, 1852), born Augusta Ada Byron, is mainly known for having written a description of Charles Babbage's early mechanical general-purpose computer, the analytical engine.

In discussing computational thinking, Jeannette Wing asks the question, "What is computable?" That is, what types of problems can be solved by computational thinking processes

carried out by humans and computers? Computatability is an important and challenging sub discipline of CIS.

I am composing this book while seated at my computer, using keyboard and mouse for input. When I turn my computer on, select a document (such as a draft of this book), and tell the computer to RUN or EXECUTE this document, I am doing computational thinking. Telling the computer system to RUN the document is actually telling the computer to select the word processing software that was used in creating and saving the document, run that piece of applications software, and then load my document into computer memory that can be used by that piece of software. The document itself contains detailed instructions to the computer program in terms of layout specifications, fonts, spacing, and so on.

The last sentence is important. When I am using a word processor, the software is not only storing the words I am writing. It is also storing detailed instructions to the word processing software on how to format the text I am writing. That is, as I write, I am creating text and I am also creating instructions to be followed by a computer program.

This level of computer programming is hidden so well from the computer user that a typical user is unaware that he or she is actually creating computer code that is later executed by a computer. A similar type of well-hidden computer programming occurs as I select a graphics package (perhaps one built into my word processor) and use the graphic tools to do a drawing. As I tell the computer how to draw various components of my drawing, the computer creates and stores detailed step-by-step directions on how to do the drawing.

A higher level of "telling" a computer what to do is illustrated by a spreadsheet. Suppose I want a spreadsheet to use in creating and following a household budget. I open a spreadsheet application program, specify a two dimensional table, enter some numbers into the table, and specify some computations that are to be carried out on various cells, rows, and columns. I might also specify that a graphical display, such as a pie chart or bar graph, be created using data from a specified part of my table.

In essence, creating a spreadsheet is a process of developing a certain type of computer model—a representation of a certain problem and steps to follow in using (manipulating) various aspects of the model. If my spreadsheet is a personal budget, I can uses it to pose "what if" types of questions as I explore various aspects of my budget.

To create my spreadsheet budget model, I had to understand the task to be accomplished, design a representation of this task, implement the representation on a computer, test the resulting spreadsheet for possible errors, and then use the spreadsheet to actually explore and possibly solve my budgeting problem.

In essence, I had to carry out all of the steps that a computer programmer carries out when writing computer programs. However, these steps were carried out in a somewhat limited context—in a context specifically designed for representing problems involving tables of numbers and computations to be carried out on tables of numbers.

Of course, spreadsheet software can also be used for other purposes. For example, many people use a spreadsheet o create, store, and manipulate a database of names and addresses.

There are many different general-purpose computer programming languages. Examples include BASIC, C, C++, COBOL, Logo, and so on. A programmer learns one or more of these languages. More important, however, a programmer learns to design, implement, and test

programs that solve or help to solve problems. The underlying computational thinking is somewhat independent of the particular language being used in the programming.

It is quite easy to learn a little bit about computer programming. It used to be common for grade school students to learn a little bit of BASIC or Logo. There are free versions of such programming languages available on the Web. Some grade school students still receive instruction in these languages or in a variety of more recently developed languages that are quite suitable for their cognitive developmental levels.

If you are interested in dabbling in a modern programming language designed for use in education, do a Google search for *Alice CMU* . and for *Scratch MIT*. Alice (developed at Carnegie Mellon University) and Scratch (develop at Massachusetts Institute of Technology) are good examples of programming languages designed for students.

Idea 3: Build Your Personal Library

As you proceed through your higher education, you should be collecting material and resources that you feel will be important and useful to you over the long run. One way to do much of this is electronically. Think of this as an ongoing, lifelong project. This section contains a few examples of categories of information that you might want to collect.

Pithy Quotations

By now you should be used to the idea that each chapter of this book begins with one or more quotations. Each has been selected because it is relevant to the ideas of the chapter and because I, personally, find it interesting. Many writers make use of such quotations in their writing.

There are many sources of quotations on the Web. When I am searching for one that might fit well into a particular book or chapter, I often encounter others that I find appealing, but that are not of immediate use to me. I save these on one of my Websites.

You can see my collection at http://uoregon.edu/~moursund/dave/quotations.htm. At the end of my list, you will see that I have written comments about a few of the quotations. The combination of a quote and my comments provides a possible starting point for a future article or chapter that I might want to write.

As you make your own collection of quotes, you might want to add comments as to why each one appeals to you—what does it mean to you, personally. Be guided by:

> "The strongest memory is not as strong as the weakest ink." (Confucius, 551-479 B.C.)

Resume

Sooner or later, you will likely have need of a well-designed resume that appropriately presents your preparation and areas of expertise. I suggest that you do three things:

1. Find or create a resume design that you feel is appropriate to your job and career aspirations. Use this design, refining it to fit your specific needs. And improve on it as your needs change.

2. Create a "current draft" of your one or two page short resume and update it periodically.

3. Create and steadily add to a much longer resume that contains items that you might someday want to refer to and that someday may be of use to you in a specific short resume. A very rough rule of thumb is that every three months you should think about what you have done during the past three months that is worthy of inclusion in your personal long resume. If three months go by in which you have done nothing worth of mention, you might want to think about what you are doing in your education, job or career, and life!

Portfolio and Electronic Portfolio

It is becoming common for grade school students to begin to develop portfolios of their schoolwork and other activities. The process includes selecting representative samples of one's work and writing a critical analysis of the work. This is an important aspect of learning to self-assess and learning to take responsibility for one's education.

Quoting from the Wikipedia:

> An electronic portfolio, also known as an e-portfolio, or digital portfolio, is a collection of electronic evidence (artifacts, including inputted text, electronic files such as Word and PDF files, images, multimedia, blog entries and Web links etc.) assembled and managed by a user, usually online. E-portfolios are both demonstrations of the user's abilities and platforms for self-expression, and, if they are online, they can be maintained dynamically over time. Some e-portfolio applications permit varying degrees of audience access, so the same portfolio might be used for multiple purposes.

Increasingly, college students are being encouraged or required to develop a portfolio of their academic work. In certain areas of study, this is a "must." An artist, architect, or musician needs to have a means of showing his or her accomplishments and levels of expertise. Nowadays, this is often done as an electronic portfolio—an e-portfolio or efolio. An efolio can contain videos showing a teacher teaching, a musician performing, a dancer dancing, and so on.

Development of a good quality efolio is a significant task. In higher education institutions requiring such work, the task is often a three-credit course that includes significant instruction in both design and production.

References

The chances are that as a student you are being expected to write a number of papers each term. Even in a short paper, the "academic quality" is apt to be improved by including some references. In longer papers, this is typically a requirement.

There are a number of widely accepted styles for bibliographic references. Thus, you will want to select one or two that are accepted in the disciplines you are studying, and learn to use these styles. You can get help in this learning process from software (such as EndNotes) and from a number of different Websites. My recent Google search of *bibliographic references* produced about 1.2 million hits.

Over the long run, you will likely find it highly advantageous to build and maintain an annotated list of references that you have used or that you feel might be useful to you in the future. The annotation for a reference need not be extensive. A sentence or two, or perhaps a copy of part of the abstract or summary of an article, will likely suffice. The goal is to provide enough information so that you can remember why you included the reference in your list.

Increasingly, you will be making use of references to material available on the Web. You will want to include a Web address for such materials. You are aware, of course, that some of these links will disappear (no longer work) sometime in the future. This is one reason for an annotation. The annotation will likely help you to find an alternant link or an alternant source of similar information.

Copies of All of Your Academic Writings

An earlier part of this section discussed the idea of an efolio. This contains exemplars of you work and each entry is accompanied by an analysis and discussion of why you included this piece of work in your portfolio.

I find it highly advantageous to keep an electronic copy of each article, talk, chapter, book, and so on that I write. I often make use of such materials as I attack new projects.

Similarly, you may want to keep electronic copies of each paper you write and each project that you do while in college. This habit will serve you well if you then end up in a job/career that requires writing reports, giving presentations, and so on.

Another thing to think about are the notes that you take in classes. Some students now use a laptop computer or tablet to take these notes. Others take handwritten notes and then organize them on a computer. Think of such tasks from two points of view:

1. Organizing and studying the notes as part of the process of learning course material and passing tests.

2. Having a record of what you have studied and learned as an aid to relearning the material sometime in the future.

This second purpose is particularly important. Research indicates that most students forget a quite high percentage of what they learn in a course. However, the course provided a foundation for retrieving information and relearning information related to the course. Thus, as you take a course, think in terms of someday wanting to retrieve information about the course content and someday wanting to relearn part of the course. Good notes created when you were taking the course can be quite helpful.

Another aspect of this note creation process is to build a briefly annotate bibliography of Websites that contain material you are learning. Select Websites that are apt to have a long life. When possible, select some Websites that are frequently updated, so that they cover the material that interests you from a current, up to date point of view.

Idea 4: Open Source Books and Other Print Materials

When I was a child, I greatly enjoyed reading Edwin A Abbott's book "Flatland." It is now out of copyright and the illustrated 1884 version is available free on the Web. Perhaps you remember this delightful book from you childhood. Quoting from the beginning of the story (Abbott, 1884):

> I CALL our world Flatland, not because we call it so, but to make its nature clearer to you, my happy readers, who are privileged to live in Space.

> Imagine a vast sheet of paper on which straight Lines, Triangles, Squares, Pentagons, Hexagons, and other figures, instead of remaining fixed in their places, move freely about, on or in the surface, but without the power of rising above or sinking below it, very much like shadows - only hard and with luminous edges - and you will then have a pretty correct notion of my country and

countrymen. Alas, a few years ago, I should have said "my universe": but now my mind has been opened to higher views of things.

This is but one example of hundreds of thousands of books that are now out of copyright. Many of these books are being made available free on the Web.

There are a number of organizations working to create large libraries of free online books. Books being added to their sites include out of copyright books, books contributed by their authors, books contributed by publishers, and so on. The legality of scanning books that are still under copyright, and making them available in an online searchable format, is being challenged.

Project Gutenberg project provides a good example of the open source movement. With the aid of a grant and lots of volunteer efforts, a large number of out of copyright books are being made available.

Quoting from Project Gutenberg (n.d.):

> There are over 20,000 free books in the Project Gutenberg Online Book Catalog.
>
> A grand total of over 100,000 titles is available at Project Gutenberg Partners, Affiliates and Resources.
>
> Languages with more than 50 books: Chinese, Dutch, English, Finnish, French, German, Italian, Portuguese, Spanish, Tagalog.

Listen to a radio broadcast discussing Project Gutenberg and other related projects at http://www.npr.org/templates/story/story.php?storyId=10136882.

Richard Baraniuk is a Professor at Rice University and Director of the Connexions project. He is a leader in the open-source learning movement. Baraniuk (2006) is a free 19 minute video: *Goodbye, textbooks; hello, open-source learning.*

The Connexions project is assembling a large collection of relatively current academic materials that the authors make available under a Creative Commons license. (The book you are currently reading is available free under a Creative Commons license.) These materials are available for viewing on the Web, organization into textbooks for students to use free on the Web or to print, and for printing hardcopy bound books at a relatively modest cost.

Quoting from Jade (2006):

> Connexions is organized around the "Content Commons," an online repository that contains thousands of scholarly modules — manuscripts roughly equivalent to two or three pages from a textbook. Connexions provides free software that allows anyone to reuse, revise and recombine the modules to suit their needs. This feature gives people the option of creating customized courses, custom textbooks, and personalized study guides.
>
> "Let's say a student is in an engineering course, and they're a little weak in math, so they want to weave in more fundamental calculus. Connexions allows them to create their own customized version of the course," Baraniuk said. "They can do that right now for free on the Web, and if they want that version in book form, then the [on-demand press] QOOP deal will allow them to have it delivered to their home within a matter of days."

Other major projects include:

- The Million Book project at Carnegie Mellon, initiated by Raj Reddy and discussed earlier in this book. See http://www.library.cmu.edu/Libraries/MBP_FAQ.html.

- Internet Archive, San Francisco. It is developing its own collection and it also provides access to a large amount of online open source materials provided by others. See http://www.library.cmu.edu/Libraries/MBP_FAQ.html. Quoting from http://www.opencontentalliance.org/:

  The Internet Archive announced on December 20, 2006 that it had achieved a milestone in having digitized and made available to date, a total of 100,000 books on its servers. The bulk of these books are from members of the Open Content Alliance. All are available without restriction to public access and enjoyment.

- Google Books Library Project is working to digitize many millions of books. See http://books.google.com/googlebooks/library.html. Quoting from the Website:

  When you click on a search result for a book from the Library Project, you'll see basic bibliographic information about the book, and in many cases, a few snippets—a few sentences showing your search term in context. *If the book is out of copyright, you'll be able to view and download the entire book.* In all cases, you'll see links directing you to online bookstores where you can buy the book and libraries where you can borrow it. [Italic added for emphasis]

- Encyclopedia of Life. World Species Project: (EoL, 2007).

  Many people have been working on pieces of this project for many years. The current idea is to join forces and fill in the gaps. Create an encyclopedia of all earth's 1.8 million known species. The information will be available free on the Web and organized to serve the needs of both researchers and students.

- National Science Digital Library. See http://nsdl.org.

  The National Science Digital Library (NSDL) was created by the National Science Foundation to provide organized access to high quality resources and tools that support innovations in teaching and learning at all levels of science, technology, engineering, and mathematics education.

- United States Library of Congress. See http://www.loc.gov/index.html. The Library is committing significant resources to build its digital collections. See http://www.loc.gov/search/new/. Quoting from the library's 2003 long range planning document:

  The Congress of the United States has been the greatest patron of a library in the history of the world—mandating and funding the programs of this unique resource for knowledge on a nonpartisan basis for 203 years. The Library of Congress under its 2004-2008 strategic plan will continue to build on its historic mission, "...to make its resources available and useful to the Congress and the American people and to sustain and preserve a universal collection of knowledge and creativity for future generations." We are faced with the greatest upheaval in the transmission of knowledge since the invention of the printing press: the electronic onslaught of digitized multimedia communication. This strategic plan will guide the Library as it superimposes a new, networked digital universe on top of its traditional artifactual (analog) collections.

Idea 5: Global Sustainability

You are part of a world that faces a large and growing problem of sustainability. The current population of humans has grown to about 6.6 billion, and it is still growing at a rapid pace. A billion people live in extreme poverty. On a daily basis, they lack adequate food, shelter, pure drinking water, educational opportunities, and other things that you probably consider the bare necessities of life. When their living conditions are expressed in terms of money, they live on less than a dollar a day per person.

The world is quite capable of providing a descent standard of living to its current population. For example, the past couple of decades of change in China and India have significantly decreased the percentage of the world's population living in poverty. Technology is playing a major role in this progress.

Some of this technology is high tech, such as providing cell telephones and their supporting infrastructure to people living in rural villages and providing basic vaccinations against some truly horrid diseases. Other is less high tech, such as providing sewer systems, pure water, and improved roads. Often *appropriate technology* (cost effective and sustainable within the income levels of the people making use of the technology) is a key to significant improvements in quality of life.

Sustainability issues have been around a long time. About 150 years ago, as London grew to be the largest city in the world, it was not at all clear that it would survive. Steven Johnson is culture/technology visionary. His book, *The ghost map: the story of London's most terrifying epidemic—and how it changed science, cities, and the modern world* (2006) follows a doctor and a clergyman who teamed up in 1854 to figure out why cholera had ravaged a neighborhood in London. The book has nothing to do with ICT, but it illustrates scientific thinking and methodology that made a huge change in our world. It also illustrates that we have come a long way in the last 150 years. For more information about Steven Johnson and his work, see:

- A 10 minute video available at http://ted.com/tedtalks/tedtalksplayer.cfm?key=s_johnson.

- A short article about Johnson and his writings available at http://www.salon.com/books/int/2006/10/30/johnson/index.html.

Sustainability, global warming, energy, and related topics are now regular topics in world, national, and local news. I enjoy reading and listening to Thomas Friedman 's insights into these issues. For a short video of Friedman discussing the energy crisis, see http://www.poptech.org/popcasts/popcasts.aspx?viewcastid=1.

If you have not yet seen Al Gore's *The Inconvenient Truth*, I recommend that you do so. Also, see the related Website http://www.climatecrisis.net/.

As you pursue your higher education and chart a path through life, think both inwardly and outwardly. Work to live a life that is appropriately balanced in helping yourself, helping others, and helping the sustainability of the world.

Idea 6: Computer Ethics

I assume that you set high ethical and moral standards for yourself and expect them of others. Ethics is the study of moral standards, and morality is:

1. standards of conduct that are accepted as right or proper

2. the rightness or wrongness of something as judged by accepted moral standards (Encarta® World English Dictionary © 1999 Microsoft Corporation)

ICT has brought a new challenge to all of us. It is now very easy to make and share electronic digital copies of intellectual property belonging to others. This book contains a number of pieces

quoted from others. You will note the large number of references for these various quoted materials.

Computer ethics deals with how computer-using people make decisions about their uses of ICT. Gradually, governments are developing laws that help to define and legal systems are working to uphold ICT "standards of conduct that are accepted as right or proper." Right now, many people ignore the laws and/or seek and find loopholes. Thus, for example, you undoubtedly receive quite a bit of email spam. Our laws and legal enforcement system have not succeeded in dealing with the spam.

Quoting from the Wikipedia:

> In law, intellectual property (IP) is an umbrella term for various legal entitlements which attach to certain names, written and recorded media, and inventions. The holders of these legal entitlements are generally entitled to exercise various exclusive rights in relation to the subject matter of the IP. The term intellectual property reflects the idea that this subject matter is the product of the mind or the intellect, though the term is a matter of some controversy.

A number of people and organizations have developed computer ethical standards. Many of the materials currently in use are rooted in the "Ten Commandments of Computer Ethic that first appeared in an article written by Ramon C. Barquin (1992) and published by the Computer Ethics Group. Here is his list:

1. Thou shalt not use a computer to harm other people.

2. Thou shalt not interfere with other people's computer work.

3. Thou shalt not snoop around in other people's computer files.

4. Thou shalt not use a computer to steal.

5. Thou shalt not use a computer to bear false witness.

6. Thou shalt not copy or use proprietary software for which you have not paid.

7. Thou shalt not use other people's computer resources without authorization or proper compensation.

8. Thou shalt not appropriate other people's intellectual output.

9. Thou shalt think about the social consequences of the program you are writing or the system you are designing.

10. Thou shalt always use a computer in ways that insure consideration and respect for your fellow humans.

Computer ethics is, of course, a worldwide issue. With the rapid improvement in telecommunications (including email and the Web), differences in commonly accepted practices between different groups of people are a major challenge. Every two years a worldwide Computer Ethics Philosophical Enquiry conference is held to help identify and discuss international computer ethics issues (CEPE, 2007).

Institute for Ethics and Emerging Technologies

The Institute for Ethics and Emerging Technologies promotes the ethical use of technology to expand human capabilities. Quoting from IEET (n.d.):

> The Institute for Ethics and Emerging Technologies was founded in 2004 by philosopher Nick Bostrom and bioethicist James J. Hughes. The IEET is incorporated as a nonprofit organization in the United States. The IEET's **Board of Directors** currently come from Spain, Canada, the UK and the United States. By promoting and publicizing the work of thinkers who examine the social implications of scientific and technological progress, we seek to contribute to the understanding of the impact of emerging technologies on individuals and societies. We also want to help shape public policies that distribute the benefits and reduce the risks of technological advancement.

Idea 7: Your Health and Life Expectancy

Most college students are interested in their short and long term physical and mental health. The Web provides access to a large number of aids that can help you address these interests.

Responsible health-oriented Websites will include some general sort of advice and warning, such as the following quote from Don R. Powell (2006):

> This book is not meant to substitute for expert medical advice or treatment. The information is given to help you make informed choices about your health. Follow your health care provider's advice if it differs from what is given in this book.

Life Expectancy

As you plan your education and your future, it might be helpful to have a good estimate of how long you are apt to live. Such estimates are statistical in nature. Thus, they cannot tell you if you will be involved in a fatal accident or contact a fatal disease next week, next month, or next year. Instead, such forecasts take into consideration the probability of such an occurrence.

Here are two sites that I have enjoyed using:

- Life Expectancy: http://www.nmfn.com/tn/learnctr--lifeevents--longevity_game The Longevity Game. Very simple and short. Easy to try experiments of the "What if …?" variety.

- Living to 100: http://www.livingto100.com/ Quite an extensive list of questions. Asks for some personal information (email address) that you may not want to provide. My suggestion is that you provide a factitious address if you do not want them to contact you. Provides good feedback and suggestions.

These sites asked for information about height and weight in order to calculate your basic mass index (BMI). There are many no hassle sites that are easy to use to calculator just your BMI. For example, see the National Institute of Health: http://www.nhlbisupport.com/bmi/.

Exercise and the Aging Brain

A person's brain reaches its full maturity at about 25 to 30 years of age. This is considerably later than full physical maturity is achieved. You know, of course, that it is important to take care of your physical body. Exercise, appropriate diet, enough sleep, and so on all contribute to this.

In recent years, research has provided us with considerable evidence of the effects of physical exercise on the brain. Quoting from an American Psychological Association document (APA, 2006):

> Based on a review of studies on exercise and its effect on brain functioning in human and animal populations, researchers find that physical exercise may slow aging's effects and help people maintain cognitive abilities well into older age. Animals seem to benefit from exercise too and perform spatial tasks better when they are active. Furthermore, fitness training—an increased level

of exercise—may improve some mental processes even more than moderate activity, say the authors of the review.

Higher education appears to have long-term cognitive health benefits. Quoting from APA (2005):

> A new study from the University of Toronto sheds light on why higher education seems to buffer people from cognitive declines as they age. Brain imaging showed that in older adults taking memory tests, more years of education were associated with more active frontal lobes—the opposite of what happened in young adults. It appears possible that education strengthens the ability to "call in the reserves" of mental prowess found in that part of the brain.
>
> Researchers hope to further understand how mental exercise strengthens mental muscles, so to speak, in old age. Animal brains respond to more complex environments by growing more neural connections; perhaps, says Grady, "more education while the brain is still developing—up to age 30 it is still maturing—causes more connections between brain regions to form. When some of these are lost with age, there are still enough left, a type of redundancy in the system." [For a more detailed discussion, see Springer et al. (2005).]

The past few years have brought us a number of companies and Websites based on the increasing evidence of the positive effects of various computer-based brain exercises for the aging brain." "Use it or lose it" is now a generally accepted statement about cognitive capability.

General Medical References

Here are some additional resources that you will likely find helpful:

- WebMD is an excellent source of information. See http://www.webmd.com/.
- Powell, Don R. and the AIPM (2006). Students' self-care guide. *American Institute for Preventive Medicine.* Retrieved 4/29/07: http://healthcenter.uoregon.edu/patientinfo/handbook/index.htm.
- Mayo Clinic. http://www.mayoclinic.com/

Summary and Self-Assessment

This chapter contains short discussions of a number of important topics. For each, you can decide for yourself whether the topic is relevant to your current interests, and whether it might be important to your future.

If the topic seems important and relevant to your life, consider developing it into an island or a broader area of expertise. In doing this, you will need to learn enough about the topic so that you can tell if you are learning what you want to learn.

Such self-guidance is an important step forward in your education. Instead of having others tell you want to learn and then providing tests to assess what you have learned, you can decide for yourself what you want to learn. You can self-assess—determine for yourself whether you have gained a level of expertise that meets your personal and professional needs.

Once you get used to the idea of developing expertise in topics of personal and professional interest, you will never run out of physical and mental challenges. There will always be advances in your chosen areas that will challenge your current level of understanding and expertise. There will always be new areas that peak your interests.

Chapter 9

On the Lighter Side

> "Now here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" (Lewis Carroll)

If you are feeling stressed, perhaps you need to "lighten up" by taking advantage of some of the lighter side of the Web. This chapter covers a variety of topics, mostly non-academic in nature.

For example, do you need to see some jokes and cartoons, or to have a joke sent to you via email ever day? Do a Google search on *free jokes*. I am sure you can find something to amuse you among the 23 million hits from this search.

Five-Minute College Education

Father Guido Sarducci is a fictional character made famous by American comedian Don Novello. Read more about him at http://en.wikipedia.org/wiki/Father_Guido_Sarducci.

Interview with the Fictional Character Father Guido Sarducci

This "interview" is quoted from JibJab Joke Box retrieved 3/22/07: http://www.jibjab.com/JokeBox/JokeBox.aspx?Id=21532&JokeId=18066,

> I find that education, it don't matter where you go to school, Italy, America, Brazil, all are the same—it's all this memorization and it don't matter how long you can remember anything just so you can parrot it back for the tests. I got this idea for a school I would like to start, something called the Five Minute University. The idea is that in five minutes you learn what the average college graduate remembers five years after he or she is out of school. It would cost like twenty dollars. That might seem like a lot of money, twenty dollars just for five minutes, but that's for like tuition, cap and gown rental, graduation picture, snacks, everything. Everything included. You know, like in college you have to take a foreign language. Well, at the Five Minute University you can have your choice, any language you want you can take it. Say if you want to take Spanish, what I teach you is "Â¿Como estÃ¡ usted?" that means, "how are you", and the answer is "muy bien," means "very well." And believe me, if you took two years of college Spanish, five years after you are out of school "Â¿Como estÃ¡ usted?" and "muy bien" about all you're gonna remember. And Latin! Forte Dux Fel Flat in De Guttor means forty ducks fell flat in the gutter. Forte Dux in Ero means forty ducks in a row. So in my school that's all you learn. You see, you don't have to waste your time with conjugations and vocabulary, all that junk. You'll just forget it anyway, what's the difference. Economics? "Supply and Demand." That's it. Business is, "you buy something, and you sell it for more." Theology, I'm gonna have a theology department, you know, since I'm a priest, and what you have to learn in theology is the answer to the question, "Where is God?", and the answer is, "God is everywhere." Why? "Because he likes you." That's kind of a combination of the Disney and Roman Catholic philosophy. It's just perfect for the late 70s or early 80s you know, just perfect. Well, after the courses are all over, then it's time for a little Easter vacation. No time to go to Fort Lauderdale, only lasts for like twenty seconds. But what I'll do for you, I like to turn on the sun lamp you know, give you a little glass of orange juice, that's for the snack part, orange juice, and then after vacation it's time for the final exams. I

say to you, "Â¿Como estÃ¡ usted?" you say "muy bien," "Where is God?" "God is everywhere," Economics, "supply and demand," Biology, God made the universe, no hastle over intelligent design or evolution, then you put on a cap and a gown, I get out my Polaroid camera, you know, make a little snap flash picture for you, I give you the picture, you give me twenty dollars, I give you a diploma, and you're a college graduate, ready to go. I'm not sure, but I'm pretty sure, right next door to the five minute university, I might open up a little law school. You got another minute?

Help Desk for the Technology Named Book

Here are two Websites where you can find a copy of a 2 ½ minute comical video about a technical support person helping a student to use the technology called "book."

http://www.youtube.com/watch?v=xFAWR6hzZek

http://www.devilducky.com/media/57946

I included two addresses, because the address I used while first writing this section did not work when I was revising the chapter. Perhaps by the time you read the book, at least one of the two links will still work. The video is from a show produced by the Norwegian Broadcasting television channel (NRK) in 2001. The spoken language is Norwegian; the subtitles are in Danish and English. The humor works well in all three languages.

Converse with an AI Computer System

There are a number of computer programs designed to carry on a conversation with a human. The underlying idea is to develop a computer program that can pass the Turing Test. The earliest of these is named Eliza and was developed in 1966. It imitated a style of non-directive therapy developed by Carl Rogers. You can converse with a computer that uses a version of Eliza at http://jerz.setonhill.edu/if/canon/eliza.htm.

A number of more modern versions of *chatterbot* programs are available on the Web. Quoting from the Wikipedia:

> A chatterbot is a computer program designed to simulate an intelligent conversation with one or more human users via auditory or textual methods. Though many appear to be intelligently interpreting the human input prior to providing a response, most chatterbots simply scan for keywords within the input and pull a reply with the most matching keywords or the most similar wording pattern from a local database. Chatterbots may also be referred to as talk bots, chat bots, or chatterboxes.

Current chaterbot programs mainly make use of weak AI, although some have a learning capability. I find it to be fun to play with some of the current programs such as A.L.I.C.E at http://www.alicebot.org/. A large list of chaterbot Websites is available at http://usa.ultimatetopsites.com/entertainment/thunder7/.

Self Assessment

There are lots of self-assessment tests available on the Web. They vary tremendously in quality and usefulness. My advice is, **"Don't take them too seriously."**

The Website http://www.allthetests.com/ is an example of a site that contains a number of self-assessment tests and links to many other self-assessment tests. I can't attest to the quality (whether they are fair, reliable, and valid) of the tests. Quoting from the Website:

> Welcome to AllTheTests.com, your route map in the exciting exploration journey into the fascinating world of Internet tests! Here you can find thousands of tests in more than 20 different

categories, and you can choose any of them depending where your interests lay. **Fun, Personality, IQ test, Love and Relationship, Quizzes, Fan Tests**—everything is possible on AllTheTests.com.

Here are some additional examples of self-assessment opportunities:

- 111 tests just for fun: http://www.queendom.com/tests/minitests/index.html.

- Depression: http://www.mayoclinic.com/health/depression/MH00103_D.

- IQ and Emotional IQ: http://www.queendom.com/tests/. My Google search of *emotional IQ* produced ell over a million hits.

- Learning styles: http://adulted.about.com/od/learningstylesqu/ and http://www.myersbriggs.org/.

- Likeability factor: http://timsanders.com/images-downloads/l%20factor%20self-assessment.pdf.

- Personality tests: http://www.2h.com/personality-tests.html. My Google search on *personality self-assessment* produced over 600 thousand hits.

- Self-assessment resources: http://www.rileyguide.com/assess.html.

- Self improvement and personal growth: http://www.selfgrowth.com/. My Google search of *personal growth* produced over 71 million hits.

- SAT practice test: http://www.petersons.com/testprep/tips.asp?id=400&sponsor=1&path=ug.pft.sat

Events in a Particular Year

Would you like to know some of the "happenings" in the world in the year you were born? I was born in 1936. I did a Google search of 1936 and got over a hundred million hits. This is, of course, an overwhelmingly large number of hits.

I now know that in 1936 the NY Yankees baseball team won the World Series, a first class postage stamp cost three cents, the U.S population was a little over 128 million, unemployment was 16.9 percent, Boulder Dam was completed, the first successful helicopter flight was made, and Franklin D. Roosevelt was elected to his second presidential term in a landslide victory over Alf Landon. Wow, that will certainly spice up my next conversation!

Here are a couple of sites that I enjoyed:

- BrainyHistory. Go to the Website http://www.brainyhistory.com/years/1936.html, but with 1936 replaced by the year you are interested in.

- Today in history. Go to the Website http://www.historyorb.com/today/index.php and scroll down to near the bottom of the page.

You can also search on a particular day of the year, such as your birthday. Or, you can search on a specific date, such as the year and date your were born. My Google search on the expression *3 November 1936* produced about 1.8 million hits.

The Best and the Worst

PC World Canada is a Canadian affiliate of the International Data Group, a large, worldwide publisher. You might be amused by PC World Canada's articles on:

- The 10 worst games of all time. See:
  http://www.pcworld.ca/news/column/e73b0b190a0104080187a604e28f6492/pg0.htm

- The 25 worst Websites of all time. See:
  http://www.pcworld.ca/news/column/38cd5e950a01040801c7c7c371d11316/pg1.htm

- The 25 worst tech products of all time. See:
  http://www.pcworld.ca/Pages/NewsColumn.aspx?id=ed7a76bf0a0104080036ef2108a2b0ea.

- The 50 greatest gadgets of the past 50 years. See
  http://www.pcworld.ca/Pages/NewsColumn.aspx?id=e550468f0a010408000b1b14a7c3c1c1.

- The 25 greatest PCs of all time. See:
  http://www.pcworld.ca/news/column/8e1804de0a01040800506ee750932078/pg1.htm

- The 50 best tech products of all time. See:
  http://www.pcworld.ca//news/column/e1823de90a01040800470a3719fcc26b/pg0.htm

Computer Games and Puzzles

The computer gaming industry is huge! The following free book captures some of my insights into this field:

Moursund, D.G. (June 2006). Introduction to Using Games in Education: A Guide for Teachers and Parents. Access at http://uoregon.edu/~moursund/Books/Games/games.html.

There is an increasing body of research on educational values of computer games. My book contains many examples of roles of games in teaching and learning. It has an emphasis on problem solving and an appendix lists and briefly discusses more than 40 general-purpose problem-solving strategies that can be learned in a computer game environment.

Here is a definition of a game:

Garris et al. (2002) define game play as "voluntary, nonproductive, and separate from the real world" (p.459). On the other hand, Jones (1999) points out that *for some people, computer and video games are real and sometimes, they are more engaging than reality.* Computer games can be categorized as adventure games, simulation games, competition games, cooperation games, programming games, puzzle games, and business management games (Hogle, 1996, citing from Dempsey et al., 1993; Jacobs & Dempsey, 1993). During the past 40 years, computer games have been played from a floppy disk, CD-ROM, with the use of email, or online through the Internet. Computer games can be played individually, against the computer, or against other people face-to-face or on-line. (Asgari & Kaufman, 2004). [Italic added for emphasis]

Notice the highlighted statement in the above definition. For many people, games are attention grabbing and attention holding. They are intrinsically motivating, and they may be addictive. This is an important idea to keep in mind as you explore possible roles of Games-in-Education. I am interested in how games can be used to improve education. At the same time, I am fully aware that games can damage a person's education and other aspects of their life. For example, it is well known that gambling games have seriously damaged or destroyed many lives!

Free Puzzles

A puzzle is a type of game. Many people generate and/or accumulate puzzles that they make available free on the Web. Some of the Web-based puzzles can be played on a computer, while

others can be printed out and used in a paper and pencil mode. A recent Google search of "*free puzzle*" produced about 150,000 hits. Many of these sites also offer free access to some games.

Here are four examples that attracted my attention:

1. Puzzle Choice: http://www.puzzlechoice.com/pc/Puzzle_Choicex.html. Provides free access to crossword, word search, number, logic puzzles, and Soduko.

2. AIMS Puzzle Corner: http://www.aimsedu.org/Puzzle/. Quoting from this site:

    > The AIMS Puzzle Corner provides over 100 interesting puzzles that can help students learn to enjoy puzzles and the mathematics behind them. The puzzles are categorized by type, and within each category are listed in order of increasing difficulty. The puzzles have not been assigned a grade level appropriateness because we have discovered that the ability to do a puzzle varies by individual not grade level.

3. Free Puzzles: http://www.freepuzzles.com/. Provides access to a large and growing collection of puzzles. Categories include: puzzle games, puzzle links, geometry, logic, math, miscellaneous, weight, and moves.

4. http://perplexus.info/tree.php. This Website uses the following categorization terms for puzzles: logic, probability, shapes, general (includes tricks, word problems, cryptography), numbers, games, paradoxes, riddles, just math, science, and algorithms.

Free Games

My Google search of *free games* returned 120 million hits. The typical site offers some free games that can be played online, perhaps some free games that can be downloaded, and some games for sale. A typical example is provided by site: *Top 10 Free Computer Game Websites* http://compactiongames.about.com/cs/freeactiongames/tp/freeGameSites.htm. Quoting from this site:

> The following websites are sites that are dedicated to providing you with free computer games or shareware games. These websites provide a good number of free computer game downloads from almost every genre of game. This list of free computer game websites is updated regularly as games and sites change.

As far back as I can remember, I have enjoyed playing solitaire games. In graduate school, a friend of mine introduced me to some two-deck solitaire games that I found particularly challenging and enjoyable. He was a very bright person who eventually flunked out of graduate school, mainly because he spent so much time playing solitaire games. Many sites provide free online play of solitaire games. A good example is http://www.acecardgames.com/en/,

If you are interested in competitive games such as backgammon, chess, and poker, you can easily find Websites that provide free online play against a computer or against human (online) opponents. For example, my Google search of free online chess produced over 2.5 million hits.

Other Free Things

- 101 fantastic freebies at http://www.itworldcanada.com/a/The-good-the-bad-and-the-ugly/bda0d981-ebfe-4e2c-ade5-fc720523eab2.html

- A wide variety of productivity tools, such as word processor, spreadsheet, graphics, and so on are available free on the Web. A Google search on *free productivity tools* will provide you with a good start in locating such tools. Google, itself, provides a number of these tools.

Video Sites

Lots of people publish video and/or photographs to the Web in order to share their work. Some of the self-publication Websites are huge and very popular.

In addition, the Internet has become a powerful competitor of the traditional radio and television broadcasting systems.

For Entertainment

YouTube, at http://www.youtube.com/, provides a good example. If you are bored and have some time to spend, go to YouTube or a similar site. There you will find a variety of "interesting, entertaining" short videos. For example, see The *Internet Help Desk* short video at http://www.itworldcanada.com/video/video3.html.

Quoting from the YouTube Website:

> Founded in February 2005, YouTube is the leader in online video, and the premier destination to watch and share original videos worldwide through a Web experience. YouTube allows people to easily upload and share video clips on www.YouTube.com and across the Internet through websites, mobile devices, blogs, and email.
>
> Everyone can watch videos on YouTube. People can see first-hand accounts of current events, find videos about their hobbies and interests, and discover the quirky and unusual. As more people capture special moments on video, YouTube is empowering them to become the broadcasters of tomorrow.

Radio and Video

Do you like to keep up to date on the news? CNN serves as a good example of what is available on the Web:

- Latest news at http://www.cnn.com/.
- Video at http://www.cnn.com/video/. "Watch breaking news, world news, politics, business, health, law, sports, science and technology, entertainment, or offbeat videos all on Free Video."

Perhaps you want a different slant on the news. There are many choices, such as:

- CBS News Video at http://www.cbsnews.com/sections/i_video/main500251.shtml.
- MSNBC Video News at http://www.msnbc.msn.com/id/8004316/.
- Fox News at http://www.foxnews.com/.
- ABC News at http://abcnews.go.com/Video/.
- BBC News at http://news.bbc.co.uk/.
- Bloomberg (business news) at http://www.bloomberg.com/index.html?Intro=intro3.

Of course, you can also spend time watching weather reports. For example, see http://www.weather.com/.

Social Networking Sites

Quoting from the Wikipedia:

A social network service is social software specifically focused on the building and verifying of online social networks for hooking up. Many social networking services are also blog hosting services. As of 2005, there were over three hundred known social networking web sites.

Here is an alphabetized list of some examples of social networking sites:

Bebo, Inc.: http://www.bebo.com/

Del.icio.us (social bookmarking site): http://del.icio.us/

Facebook: http://www.facebook.com/

Flickr (photo sharing site): http://www.flickr.com/

friendster: http://www.friendster.com/

iVillage Connect: http://www.ivillage.com/connect?ivNPA=1&sky=ggl|ivl|networking|ot|Hee

My Space: http://www.myspace.com/

Second Life: http://secondlife.com/

Summary and Self-Assessment

It feels a little strange to me to end a "serious, academic book" with this "On the Lighter Side" chapter. However, this chapter provides a glimpse into a major change going on in our world. It is a change to anywhere, anytime access to information and various forms of entertainment. It is a change to anywhere, anytime multimedia communication. It is a change to empowering individuals who have something they want to communicate and share.

This anywhere, anytime access can be used in a passive solitary mode, as you browse the news, weather, and sports. It can be used in a more active solitary mode as you play solitaire games or play games with the computer as an opponent. It can be used in a still more active mode as you buy and sell, conduct business of all sorts, communicate with colleagues, friends, and relatives.

This anywhere, anytime connectivity is a powerful change agent. Are you getting an informal and formal education that helps prepare you for life in our rapidly changing world? Remember, the pace of change is increasing!

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Index