A College Student Guide to Computers in Education

Dave Moursund's next book is scheduled for completion in Summer 2007.

The material you are currently reading is a 4/26/07 draft of part of the book. Access this draft at: http://uoregon.edu/~moursund/Books/CollegeStudent/CollegeStudent.html

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This short book is for undergraduate and graduate college and university students, and for others thinking about enrolling in higher education courses. It is designed to help you get an education that prepares you for life in our rapidly changing Information Age. The information and ideas presented will help you to gain a competitive advantage over your fellow students and others who lack appropriate insights into how Information and Communication Technology is changing our world.

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.

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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 40 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/.

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Preface: Read This First!

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

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

This is a book 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.

Writing for Online Reading

You are living at a time of rapid technological change. 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. 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 the field of Information and Communication Technology (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.

However, there may be something about this person who was raised in India, who has risen to prominence in the United states and the world, and who is working to improve the lives of rural people in India and throughout the world. If this topic interests you, then 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. 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 books project to get a million books scanned and available 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. Also, see Chapter 5 of the book you are currently reading.
- 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.

Your exploration of Raj Reddy and his work might lead you to want to know more about Alan Turing, a pioneer in the early development of computers and Artificial Intelligence. There is lots of information 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 it 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 he "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 hand copy) libraries will be of value to you throughout your lifetime.

Notice also that I made use of 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.

This Book Tells a Story

Many years ago, perhaps even before you started school, 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 sound patterns in your head.

Eventually you began to read chapt*er books* (books made up of a sequence of chapters) and you began to learn through the process of reading. The expectation is that 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 college students and older people select a math 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 is not a storybook, but it tells a story. The story is 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 central character and 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 do 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 level 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.

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 provide.

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 a textbook 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, a textbook 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..

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.)

Increasing Your Levels of Expertise

By going to college, you have the 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 help 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. The two major results are that computer technology is:

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

This book also touches on a variety of topics that are not directly computer-related. For example, there is a section on Brain Science. This is in the 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.

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 Lighter Side

Although this is a somewhat "heavy" book, it also has a lighter side. See Chapter 8: Just for Fun and Self-Assessment. In addition, here are two Websites where my might 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 chapter 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.

Chapter 1

Some Key Ideas in this Book

> "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)

This first chapter briefly introduces and summarizes the most important ideas in the book. Most of these ideas are revisited in later chapters. Many of these are powerful ideas, and they can change your life. In the brief presentation of these ideas, I was torn between organizing them from what I consider most important to less important, and organizing them in the order of the remaining chapters of the book. The result is somewhat of a hodgepodge. Ultimately the importance of each idea needs to be judged by you, the reader.

Idea 1: Auxiliary Brain

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

You are also used to the idea of creating and maintaining a personal library of information. Your library may consist of physical books and magazines, notes taken in courses, address book, recorded music, videos, photographs, and so on.

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 processing of information. Somewhat in the sense that you merely need to tell a calculator the numbers you want operated on and the arithmetic operation to perform, merely telling the 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 where it is (where you are) located on the surface of the earth.

I find it helpful to think of a computer as an *auxiliary brain*. The computer as an auxiliary brain has strengths and weaknesses. A strength is that it can easily memorize large amounts of information and hold this information in memory for many years. A typical book is less than a million bytes (a million characters) in length. This amount of computer disk memory costs less than a tenth of a cent. Thus, you might want to store a copy of this book on your computer, so that it is readily available for reading, searching, quoting, copying (subject to the Creative

Commons Attribution), sharing with others, and so on. As you make use of your personal electronic copy of this book, you can insert your comments and ideas into the text, much like you do when you underline text in a book and write margin notes. You can write summaries of ideas that you think are particularly important and keep the notes in a readily accessible file, or perhaps as a Chapter 0 in the book.

I strongly suggest that you take this same approach with anything that you read online that you consider of potentially lasting value to you. Build a personal electronic library, annotated with your thinking, and store it on your computer. The automatic indexing features now available for personal computers will make it very easy for you to find and retrieve this information for use in the future. If you intend to make "scholarly, academic" use of some of your stored materials, then make sure that these items are accompanied with an appropriate bibliographic citation. Thus, when you retrieve an item and make use of it in writing a paper, you can copy the citation into the reference section of your paper. Of course, you will also want to remember to keep a electronic copy of each such paper you write, as pieces of it may be useful in your future writings.

Idea 2: Procedural and Computational Thinking

A computer is a machine that can quickly and accurately follow (execute) a detailed step-by-step set of instructions called a computer program. It is easy to learn to write simple computer programs. For example, many grade school children learn to write programs in the programming language Logo or BASIC.

However, it requires a great deal of problem-solving ability, creativity, education, and training to acquire a high level of expertise as a computer programmer. The problem solving and creativity are used to design and develop detailed procedures for solving a particular category of problems or accomplishing a particular category of tasks. These procedures are then represented in a programming language. The program is then tested and its errors (bugs) are corrected.

Many of the computer programs that are now in routine use are developed by teams of problem analysts, programmers, graphic artists, and program testers. A medium-sized project, such as developing a new graphics-intensive computer game, may require a team of a dozen people working together for a year or more. Very large projects may require a team with hundreds of members working over a period of years.

The type of thinking required in such computer program development came to be called procedural thinking. More recently, the expression *computational thinking* has come into widespread use as a broadening 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.

> *Computational thinking is a fundamental skill for everybody, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability.* [Italics added for emphasis]

Students need to pay particular attention to the two questions:

- What can humans do better than computers?
- What can computers do better than humans?

Answers to these two questions vary from discipline to discipline and from course to course.

The definition of computational thinking stresses that both human and machine intelligence are being used, each contributing what it can to solve a specific type of problem or accomplish a specific type of task. Chapter 4 explores human and machine intelligence.

Idea 3: 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 wisdom and foresight. (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 why 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 this self-responsibility away from students.

Higher education has some propensity to continue your education along the path of *tell me what to do and I will do it.* Consider a different path—the path you will need to follow once you get out of school. This 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. 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 an awesome and rewarding journey.

Information and Communication Technology (ICT) has given us new aids to learning. For example, the Internet is a broad-based 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.

Idea 4: 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. Moreover, 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 IT, 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.

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

Idea 5: Expertise

There is a difference between having a certain level of expertise in an area and being an expert in the area. Think about various areas where you have an appreciable, useful level of knowledge and skills. Your actual level of knowledge and skills varies considerably from area to area. In some, you may consider yourself a beginner, functioning at a novice level. In others, you may well have a level of expertise that is quite high relative to other people.

I find it helpful to use the scale in Figure 1-1 to talk about varying levels of expertise. Probably your levels of expertise in various areas (such as A, B, and C in the figure) differ considerably.

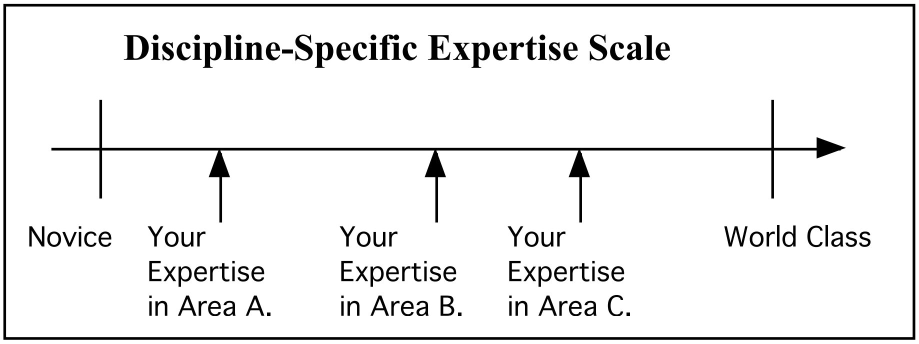

Figure 1-1. Expertise scale.

Figure 1-2 places greater emphasis on a level of expertise that you consider personally useful or that a potential employer might consider useful. Of course, when you are looking for a job, you typically will be drawing upon your level of expertise in many different areas. You might have exceptionally good interpersonal skills to go along with your high level of accomplishment in a specific academic discipline. Usually, a particular job requires a reasonable level of expertise in a variety of areas.

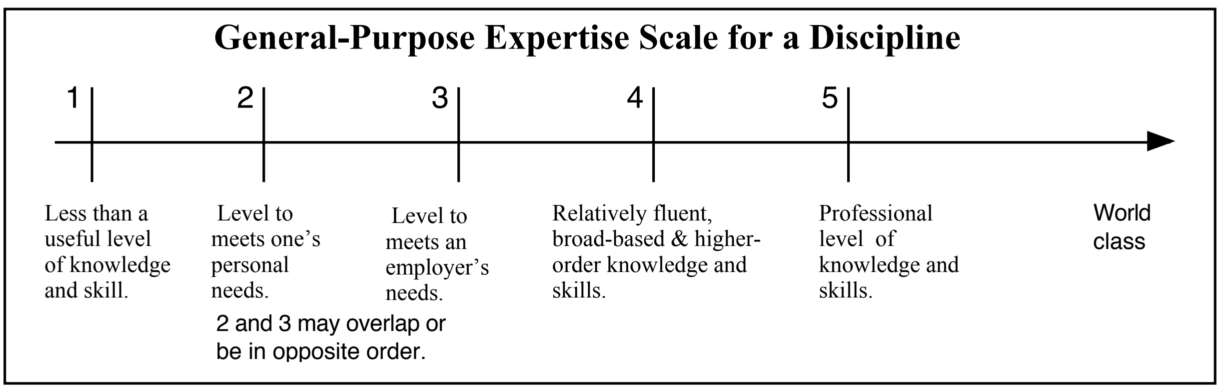

Figure 1-2. An expertise scale stressing levels of usefulness.

Here is a simple-minded way to think about your goals in higher education:

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). I cases where one can accumulate evidence of increased expertise (such as handicap in recreational or competitive golf), 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.

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.

Idea 6: Communicating with ICT Systems

You may not realize it, but you routinely communicate with very complex ICT systems. You do this when you are making a telephone call, downloading and listening to music, using a digital camera, making an ATM withdrawal of some cash, doing a search for information on the Web, sending and receiving email, and driving a relatively modern car.

To use a fancy word, computers are ubiquitous. In many cases, it is easy to communicate with a computer system and tell it what you want done. Indeed, there is an increasing trend to being able to talk to a computer system—that is, use voice input—when telling I what you want done.

It hasn't always been this easy. Indeed, instructions were given to the first electronic digital computers by changing wiring connections and by setting switches. Next came the use of coding instructions in punched paper tape and cards, and the idea of an electric typewriter to type instructions into a computer's memory. One needed extensive training in computer programming to be effective in telling a computer what to do.

Gradually, however, it became clear that a person could learn to make minor modifications to a set of instructions prepared by a computer programmer, and thus communicate with a computer without being a computer programmer. This trend has continued, so now you can make extensive use of a computer and of other ICT systems without knowing much of anything about computer programming. This works well as long as someone else has done the work behinds the scenes, so all you need to do is make minor modifications to software that has been designed to solve a type of problem that you are facing.

However, this analysis is somewhat misleading. I will illustrate this using the writing of this book as an example. I am writing this book using software named Microsoft Word, running it on my Macintosh computer. As I write, I am also doing the layout for the final publishing of the book. That is, I am formatting the book for desktop publication.

Before I started to write the book, I decided on the layout of the pages and I developed a set of styles (detailed layout specifications) for the paragraphs, headings, tables, and so on. I gave this set of information to my copy of Microsoft Word.

As I write, from time to time I decide that a particular word or sequence of words should be included in the book's index. I select the word or sequence of words, and using keyboarded instructions tell the computer to include it in the index. Somewhat similarly, I select chapter titles and section headings, and specify how they are to appear in the Table of Contents. When I want to view the current Index or Table of Contents, I instruct the Microsoft word system to update my Index and Table of Contents. To update the Index, the computer looks through the entire text I have written, selects each item that is to go into the index, notes its page number, alphabetizes the list, adds in the page number references, and places it all on the page(s) in the two column, 10-pont type that have specified for the Index.

There are a huge number of other programs built into Microsoft Word. For example, I can tell the system to alphabetize a list (such as my references) check for spelling errors and suggest corrections, automatically correct certain spelling errors or typos without even bothering to tell me it is doing so, do a global (whole document) or a local search and replace, change the typeface and type size being used in the document, change the layout of the pages, and so on. I have seen estimates that the typical user of the Microsoft Word software makes use o well under five percent of its capabilities.

Spreadsheet software offers a different challenge. Creating, testing, and debugging a spreadsheet has many of the characteristics of writing a computer program. In essence, spreadsheet software provides a restrictive computer-programming environment. While it is easy to make simple uses of a spreadsheet, it is a significant learning challenge to gain the knowledge and skill in making effective use of spreadsheets to address novel (new, challenging) problems.

There are many powerful pieces of software that require a substantial learning effort. Most of these pieces of software allow one to quickly acquire a personally useful level of expertise. However, each can take years of education, training, and experience to acquire a high level of expertise.

Idea 7: Change and the Future

When you were a young child, everything was new, so adjusting to change was a natural and necessary survival trait. As people grow older, many have an increasing level of difficulty in adjusting to change.

The Agricultural Age began about 12,000 years ago. Before that time, all people were hunter-gatherers. For most, life was very challenging. However, the pace of change was very slow. Life in a hunter-gatherer society changed little over hundreds of years. The world's total population was perhaps 12 million, so people were widely scattered and isolated. Transportation was mainly walking, and communication was mainly talking.

Agriculture led to population growth, and the development of villages, towns, and cities. The increased population supported specialists who developed a high level of expertise in relatively narrow areas. A person might make a living by woodcarving, basket making, or pottery making. The greater population density and improvements in transportation facilitated the types of change that come from technological and social development.

The development of reading and writing a little over 5,000 years ago allowed a new way to store and retrieve information. This way of accumulating information led to a significant increase in the pace of change. You have heard the expression, "Don't reinvent the wheel." The basic idea is to build on the creative work of others, and use your creative efforts in a manner that others can build upon in the future.

Improvements in transportation, communication, information storage and retrieval, and education all contribute to an increasing pace of change. A person deals with change by learning about and adjusting to new things. One prepares for these learning challenges by learning to learn. Thus, a good modern education is appropriately balanced among general learning, specialized learning (perhaps developing a high level of expertise in one or more areas), and learning to learn and to adjust to change.

The first commercial production of computers in the United States occurred in 1951. In the early 1950s, computers were sufficiently cost effective to justify their construction and sale to a limited number of organizations, such as to governments and big businesses. Since then, the price to performance ratio of computers has improved by a factor of approximately 10 billion!

Ten billion is a very large number. This improvement in computer technology has led to huge changes in many different aspects of life in this country and throughout the rest of the world. The human genome project provides a good example of how rapidly technology is changing. The US Federal Government invested nearly $3 billion in the project that began in 1990 and ended in 2003. Current costs of sequencing a person's genome are estimated to be perhaps $10 to $15 million, and various organizations and people believe that the cost may eventually be as low as $1,000 (Wade, 2006).

Ray Kurzweil's book: *The Singularity is Near: When Humans Transcend Biology* was published in 2005. This book contains a number of forecasts, with a special emphasis on genetics, nanotechnology, and robotics. The book also contains carefully argued analyses of the possibilities of continued exponential growth (indeed, an acceleration in the current exponential growth) of computer capabilities. The analysis and forecasting sections of Kurzweil's book contain considerable data on historical trends as well as examples of ICT-related and ICT-facilitated recent progress in various technologies.

If nanotechnology is not yet part of your insights into the future, you may want to change this situation. A good report of what is coming down the road is available at Emerging Nanotechnologies (2007). For a video summary of the report see http://www.wilsoncenter.org/index.cfm?topic_id=166192&fuseaction=topics.event_summary&event_id=233295#.

The *singularity* referred to in the title of his book is a time when computer intelligence exceeds human intelligence. Quoting his book (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.** [Bold added for emphasis.]

In brief summary, the technology-based changes that have occurred during the past few decades are small relative to what the next few decades are apt to bring!

Idea 8: Scholarship of Teaching and Learning

Formal schooling has existed since the invention of reading and writing. Over the past 5,000 years, there has been a slow but steady increase in the accumulated knowledge and skills in effective, efficient teaching and learning. Indeed, we now have a well-established discipline called the Scholarship of Teaching and Learning. A narrower, more research based aspect of this discipline is called the Science of Teaching and Learning. The discipline of cognitive neuroscience (brain science) is now making significant contributions to the Science of Teaching and Learning. In this book I use SoTL to refer both to the general scholarship and to the science of teaching and learning.

Your entire life has been a time of informal and formal learning. Your brain is genetically designed to be good at learning. Through your years of informal and formal learning, you have acquired considerable knowledge and skill as a learner.

Unfortunately, some of this knowledge is incorrect. Some of your learning skills are quite inefficient and ineffective. There is an extensive literature about study skills available on the Web.

Your formal schooling has probably contained relatively little about the past few decades of rapid progress in the SoTL. For example, think about what you know about metacognition, reflective learning, constructivism, and situated learning. Think about what you know about transfer of learning (have you heard about the high-road, low-road theory of transfer of learning). What do you know about how recent research in cognitive neuroscience (brain science)?

Information and Communication Technology (ICT) is providing us with a variety of new aids to teaching, learning, and making use of what one has learned. Our precollege and higher education systems of formal education have been slow to adjust to possible changes based on ICT and SoTL. You, as a student and learner, need to fill in the gaps and make sure that you receive a modern education.

Looking at me as a writer of scholarly books provides a simple example. As I write, I make routine use of my auxiliary brain. I make use of a word processor with a spelling checker and a grammar checker. As needed, I make use of a spreadsheet and graphics software tools. I draw upon my past 20 years of writings stored in my computer. I routinely email professional colleagues to ask for information and to discuss ideas. I am on a number of distribution lists that automatically email me information about my areas of interest. I routinely use the Web to search for relevant research-based literature. I also routinely draw upon my personal hardcopy collection of books and journals that sit conveniently near my computer desk.

Idea 9: Academic Disciplines

In your precollege education, you studied disciplines such as art, health, math, music, reading, science, social science, and writing. Each of these disciplines includes a number of sub disciplines. For example, biology, chemistry, geology, and physics are four well-known sub disciplines of science.

Moreover, there are important crosscutting disciplines such as physical chemistry and molecular biology. Indeed, most of the problems that people encounter and deal with in their lives tend to be interdisciplinary. Our educational system is divided into discipline-specific departments, programs of study, and courses, with the hope or expectation that students will be able to take their discipline-specific expertise and apply in to problems in other disciplines. That is, they expect *transfer of learning* to occur. Research indicates that our educational system can be significantly improved through more specific teaching for and practice in transfer of learning.

There has been considerable research on how much time and effort it takes a person to achieve a high level of expertise in a discipline. Typical answers suggest that it takes perhaps 10,000 to 20,000 hours of concentrated effort to "be all you can be" in a specific discipline. This will be discussed more in the Chapter 3, on *Expertise and Problem Solving*. The point is, a one term college course or a year sequence, counting class time, homework, and studying, constitutes a very small fraction of what it takes to achieve a high level of expertise. Within each academic discipline, there are people who have put in the needed 10,000 to 20,000 hours to achieve a high level of expertise. Often this long road includes earning a doctorate and working in an academic setting, such as being a professor in a college or university.

Information and Communication Technology is now important in every academic discipline. ICT can be an important part of the content of a discipline, an aid to teaching and learning in the discipline, an aid to assessment in the discipline, and an aid to solving the problems and accomplishing the tasks of the discipline.

Idea 10: Threats and Opportunities

Computer technology is a powerful change agent. A technological change provides possible advantages and opportunities to many people, states or regions, and nations. However, it provides possible disadvantages and threats to other people and nations.

In times of rapid change, some people with have the ambition, drive, time, energy, and resources to become early adopters and perhaps secure a major advantage over others. You should think about this as you set and pursue your higher education goals. ICT uses in each academic discipline present an opportunity for you to develop an area of expertise that may give you a significant advantage in a particular discipline. All you have to do is gain both "traditional" expertise within the discipline and gain expertise in modern uses of ICT within the discipline.

Now consider how this new technology is a threat to the establishment and employees. The new technology may be the basis for significant changes in products and services. It may require a substantial amount of new learning and changes in ways of thinking by the employees. Once a company is well established in its business or an employee is well established within a job or career, major changes are difficult. New companies with better-educated employees may seize market share and outperform the better-established companies.

It can be quite useful to talk about winners and losers, and that technology is not neutral. However, technological inventions sometimes provide very widespread benefits. The cell telephone and email provide good examples. For non-ICT examples, think about the worldwide success in nearly eradicating polio and smallpox.

I make routine, extensive use of email. It is an important aspect of my everyday life. Perhaps this is also true for you. However, have you ever done the following?

- Sent email to everybody on a list when you really just want to send a personal response to one person on the list.
- Sent an email message and then immediately have second thoughts, and wished you had not sent the message.
- Wasted a large amount of time because of spam email.
- Had a virus introduced into your computer system through email sent to you.
- Failed to organize and save the email messages you have sent and received in a manner that makes it easy to refer back to earlier parts of a sequence of email correspondence.

The Web provides another good example of threats and opportunities. The Web makes it easy to steal or plagiarize. Intellectual property rights have long raised challenging issue, and ICT brings new dimensions to these issues. Such easy opportunities to steal or plagiarize are a threat both to others and to oneself.

I find it quite useful to have access to the huge amount of material available on the Web. However, many of the documents that I retrieve are of dubious quality. When I am searching for some specific information I need, Often, I am overwhelmed by the many thousands of “hits” identified by my search engine. These difficulties are examples of Web-based threats.

We are all familiar with the excuse, “My dog ate my homework.” The more modern version of this excuse is, “My computer ate my homework.” In this case, the “ate” may mean a lost or erased file, a hard disk crash, or other computer calamity. As a computer user, you need to learn to take responsibility for frequently saving your work and for making back up copies saved in a secure manner.

Finally, think of the threats posed by ICT if you fail to learn to make effective use of this technology, others will learn, and you may suffer a competitive disadvantage.

Information Explosion

The totality of accumulated knowledge is huge and growing very rapidly. In an average day, there is far more content added to the Web than you could read in a lifetime. While estimates vary widely, many “experts” think that the totality of accumulated human knowledge is doubling every five years or so.

As you involve yourself in informal and formal education, you will continually be making decisions about areas in which you will attempt to increase your level of expertise, and what level of expertise you are aiming for. Even in a relatively narrow discipline, you will not be able to learn all that is known and then continue to learn all the new information, knowledge, wisdom, and foresight that is being discovered and developed.

ICT provides two valuable aids to dealing with information explosion. First, much information can be readily retrieved from the Web and other sources. Thus, you can retrieve information when you need the information. That is quite different than trying to memorize information and retain it in your brain for possible use sometime in the future.

Second, there is a rapidly growing accumulation of information represented as procedures that computers, computerized machinery, and appropriately educated people can carry out. Computational thinking is an important part of an answer to information explosion.

Example of Self-Assessment

Here is an example of a self-assessment activity. This chapter begins with the following quote:

> “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)

Here are three questions about this quote:

1. What does the quote mean to you?

Do you understand the words information, knowledge, wisdom, and foresight? Can you give personal examples in which you have made use of information, knowledge, wisdom, and foresight? How has your formal and informal education better prepared you to make use of the ideas conveyed in this quote? Can you restate the quote in your own words?

2. Who is Arthur C. Clarke?

   Who cares what he said sometime in the past? What did he do to deserve to be quoted at the beginning of this chapter? What has he done that is related to the content of this chapter?

3. Have you started your own personal collection of pithy quotations? I keep my personal file of such quotations on a Website, so that others can access them. See http://uoregon.edu/~moursund/dave/quotations.htm.

If I were teaching a course that used this book as a required text, it is *highly unlikely* that I would ask these questions on a test. Indeed, if I were writing a book on study skills, I might include a statement such as, "Many professors like to include pity quotations at the beginning of a chapter. Often this is done to make their book seem more academic and respectable to their colleagues. Unless the text specifically refers back to the quoted material and discusses it in detail, you can safely skip the quotations."

Courses and books are designed as aids to learning. It has taken me perhaps fifty to a hundred times as long to write this book as it will take you to read it. However, there is a substantial difference between reading (passing you eyes over the pages and letting the words flow into your brain) and reflective reading for learning and understanding.

Reread Clarke's statement, and ask yourself: What does it take to turn information into knowledge? Is knowledge remembered longer, and is it more useful than memorized information? What does it take to turn knowledge into wisdom? What does it take to turn wisdom into foresight? Hmmm. This one short statement by Arthur C. Clarke hits at the very core of education. Thus, a person could spend a lifetime exploring the meaning and ideas in Clarke's statement.

Summary and Self-Assessment

Each chapter ends with a section titled *Summary and Self-Assessment*. The Summary captures a few of the key ideas from the chapter. The Self-Assessment is your chance to increase your expertise in **Being a Responsible Adult Learner.**

There are two important themes introduced in this chapter. The first is that you can take increased responsibility for your own learning. That is, you can increase your level of expertise in taking self-responsibility, and you can learn to make routine use of this increased expertise. The second is that ICT and many other technologies are helping to change our world and the lives of people living in our world. In your informal and formal education, you have the opportunity to increase your levels of expertise in ICT and other technologies. This book is designed to help and encourage you to do so.

You are used to taking tests, writing papers, and doing other activities that are assessed by the teacher and that contribute to your grade in a course. Indeed, you may well put in considerable time and effort trying to "out fox" the teacher and to achieve passing or higher grades with only a modest amount of learning effort.

Perhaps you think of formal education as a game, where the goals are to pass courses and to complete the requirements for a degree or a particular certification. My recent Google search of the quoted expression *"test taking"* returned more a million hits. It may well be that you will want to increase your expertise in test taking by spending time reading some of these Websites and practicing the ideas they suggest.

However, there is much more to higher education than passing courses and getting a degree or certificate. You want to increase your expertise as a learner, and you want to gain increased expertise in a variety of areas that you feel are relevant to you now and in the future. Self-assessment will help you in both endeavors.

To return to some of the ideas of self-assessment, think of this entire chapter as one long quotation from David Moursund. Then you can ask yourself the same questions I asked about the quote from Arthur C. Clarke.

Obviously, you do not want to spend a lifetime reflecting on the content of the first chapter of just one of my books. However, you may want to reflect for a while on three key questions:

1. If you were going to remember and make lifetime use of just one or two ideas from this chapter, which ideas would you select, and why?
2. How might you go about consciously working to maintain and increase your level of expertise in the areas of the ideas you select in (1) above?
3. How will you be able to tell next week, next month, next year, or many years from now whether you still remember and are still making use of these ideas, and have a level of expertise in these ideas that meets your needs?

The first question might lead you to paging back through the chapter, identifying possible key ideas, and reflecting on their personal importance to you. The second question gets you to think about maintaining and building your level of expertise in an area that interests you. The third question focuses on self-assessment now and in the future.

Note that these questions can be applied to any chapter of any textbook, any class lecture, and so on. They represent an important aspect of good study skills.

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.)

I hope that by now you are reading the "pithy" quotes at the beginning of the chapter and reflecting 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 general forecasting techniques.

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 early 1950s, 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 six years.

Even at that speed and cost, the early computers were cost effective on some jobs. 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.

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 seventy-five cents. The transistor had been invented only a few years earlier and initially cost far more than 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.

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.

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 is another specific example. The Russian satellite Sputnik was launched into orbit in 1957. Now, dish TV and satellite-based Global Position 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 US Federal Government invested nearly $3 billion in the project that began in 1990 and ended in 2003. Current costs of sequencing a person's genome are estimated to be perhaps $10 to $15 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.

Ray Kurzweil (2005) is a 36-minute video presenting ideas about forecasting the future of information technology. He argues that it is possible to make relatively accurate forecasts of some of the current research and development in information technology. He points out that the pace of change of technological change is increasing, and he makes a number of forecasts for the next couple of decades. There is a very good chance that you will live long enough to see how accurate his forecasts turn out to be.

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 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 the faces a steadily increasing pressure on the world's resources, worldwide competition for these resources, and a steadily increasing challenge of sustainability.
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 some of the people who are creating the future of CIS and 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.

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'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. He has received seven national and international film awards. Ray's books include The Age of Intelligent Machines, The Age of Spiritual Machines, and Fantastic Voyage: Live Long Enough to Live Forever. Four of Ray's books have been national best sellers and *The Age of Spiritual Machines* has been translated into 9 languages and was the #1 best selling book on Amazon in science. Ray Kurzweil's new book, published by Viking Press, is entitled *The Singularity is Near, When Humans Transcend Biology*.

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 L. 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).

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. This 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. If you make cashmere sweaters or Chinese food, it will be a long time before we can convert them to bits. "Beam me up, Scotty" is a wonderful dream, but not likely to come true for several centuries. Until then you will have to rely on FedEx, bicycles, and sneakers to get your atoms from one place to another.

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. A physical copy of the book can sit in a repository, and it takes considerable time and effort for physical copies of it to be made available to a large number of people. The same situation holds for distributing music electronically via the Web, and distributing it on hard copy media such as disks.

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 $135 to $140, but the expectation is that eventually they will cost well 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 video listed below. Learn more about Negroponte and his work at:

- 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.

Malcolm Gladwell: The Tipping Point

Malcolm Gladwell is the author of *The Tipping Point* (2000) and Blink (2006). *The Tipping Point* explores the dilemma that many companies have faced in the past and at the current time. Consider a successful company that makes a variety of well-accepted products. How does this company deal with proposed new products that its own researchers and developers are working on, but that will compete with its currently quite successful products?

The Tipping Point provides a number of examples in which major, successful companies were unable to effectively deal with such challenges. The company is doing well, dominating in its business area. Why should it change? Indeed, rather than change in a timely manner, many such companies have eventually gone bankrupt.

Several of Gladwell's examples come from the computer industry. They provide excellent insight into the difficulties in dealing with a fast pace of technological change.

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 writings and insights into the world.

- 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.

ICT is Worldwide

Many people who live in the United States assume that the US 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 free 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 may prove quite useful to you. Even back 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 fellow students, your teachers, or your parents.

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 an island 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

> "In short, learning is the process by which novices become experts. " (John T. Bruer. *Schools for Thought,* 1999, page 13.)
>
> "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 schooling designed to teach reading, writing, and arithmetic goes back more than 5,000 years, to the time of the invention of reading and writing. The 3Rs are mind tools, and to the human brain. It takes considerable time and effort to develop a level of expertise in these disciplines that meets contemporary standards.

However, whatever your level of expertise in these areas, it 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 I s part of every discipline, and it is also 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 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 7-1 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 the topics being taught in a course.

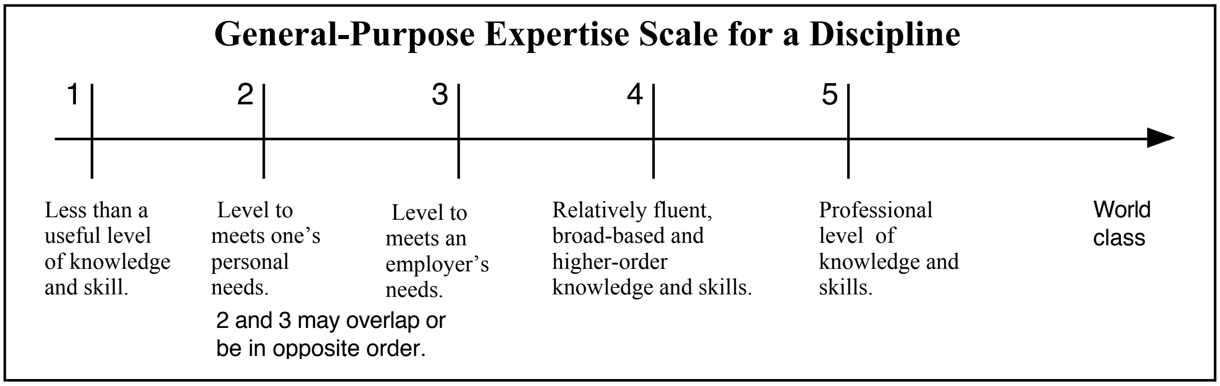

Figure 7-1. General-purpose expertise scale.

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 7-2.) 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.

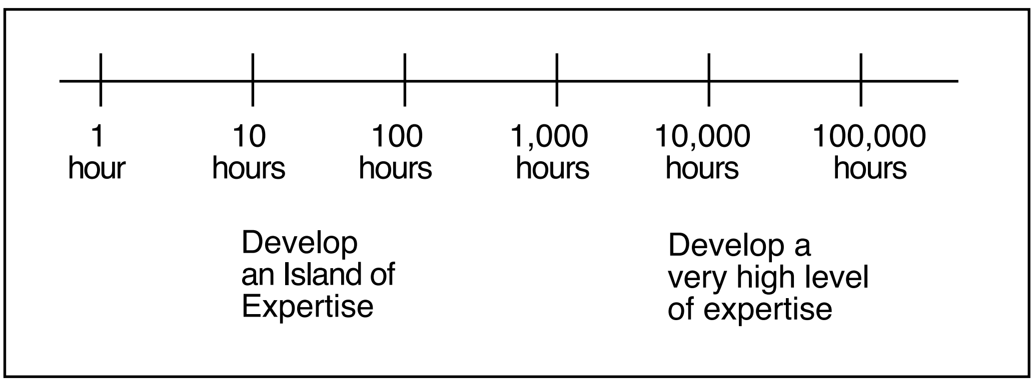

Figure 7.2. Time to develop expertise.

"Be all you can be" lies in the 10,000 to 100,000 hours range, or in the 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, 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. John Hayes of Carnegie Mellon has shown that modern symphony orchestras almost never perform or record Mozart's childhood compositions, and argues that Mozart's early works would have long ago been forgotten, were it not for his mature masterpieces. In other words, Mozart's genius wasn't innate or instantaneous—he learned how to write immortal symphonies by writing lots of mediocre ones.

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. "Other golfers may outplay me from time to time," Woods wrote in his book, "but they'll never outwork me."

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 five 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]

One of the key ideas here 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.* It is interesting to note that time spent playing chess, even in tournaments, appears to contribute less than such study to a player's progress; the main training value of such games is to point up weaknesses for future study. [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 "result" is shared, demonstrated, or used as a product, performance, or presentation.

The bulleted list given above is another example of a challenge to students reading this book as a required part of a course. You have been solving problems and accomplishing tasks all of your life. Your goal here is to broaden your internal model of the terms problem and problem solving. You want 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.

It is common to think of expertise in terms of performance in solving the problems and accomplishing the tasks within a discipline or subdiscipline. There is a large amount of research on teaching and learning problem solving. One can study aspects of problem solving that cut across all disciplines, and one can study discipline-specific aspects of problem solving.

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 telephone 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 coursework.

The fourth part of the definition of a problem is particularly important. Unless a student has ownership—an appropriate combination of intrinsic and extrinsic motivation—the student does 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 introduction to 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 *The Goals of Mathematical Education* (Polya, 1969) transcribes a talk he gave to a group of elementary school teachers. Some of his comments, I think, are relevant to all students:

> 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.* [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. 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 (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 work on a problem. 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 an 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 provide 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? Did the problem-solving ask make use of both low-road and high-road transfer of learning? What did you learn during the problem solving process that will likely be useful when you encounter other somewhat similar problems I 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 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).

To summarize, one goal in the study of an academic discipline should be that students 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.

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: Ericsson

> 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, as does its contribution to building a useful level of expertise.

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 were taking a course in which the book you are currently reading was 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 in various disciplines.

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 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?

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!

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 pat is a handicap to future learning. Thus, it behooves you to identify important deficiencies in your education and to spend time correcting in these deficiencies

When you encountered the word *disciplin*e in the previous section, 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. These various possible meanings are tied in with who and what you are. Your life experiences related to the word are different from those of any other person.

However, there is enough similarity between what *discipline* means to you and to others so that you can communicate with others by using the word orally and in your writings. You and others hold in mind somewhat similar definitions. The definitions are enough alike so that human-to-human communication can occur. Moreover, your mental definition is likely good enough so that you can use it in retrieving and understanding information from the Web, from resource books, and so on.

Thus, when you encounter a new word or idea when reading an academic text, think in terms 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.

Situated Learning Theory

Situated learning is a theory that says 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 a building or cabinet.

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

One of the most important ideas in learning 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.* Thus, the prospects and conditions of transfer are crucial educational issues. [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.

The human brain functions by recognizing patterns and then acting upon these patterns. Low-road transfer is associated with a particular narrow situation, environment, or pattern. It is associated with rote memory. Consider the situation of students learning single-digit multiplication facts. This might be done via work sheets, flash cards, computer drill-and-practice, or a game or competition. For most students, one-trial learning does not occur. Rather, a lot of drill and practice over an extended period, along with subsequent frequent use of the memorized facts, is necessary. Some students learn much faster than others using these methods.

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 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.
3. Identify a number of different examples in other disciplines and situations in which this named strategy is applicable.

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 an game playing.

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 area in which you are developing expertise.

Finally, work to increase your skills in metacognition, in reflecting about all aspects of how you deal with the problems, tasks, and decisions that you make throughout your everyday activities and in your studies.

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