Getting Smarter At Solving Problems: Preliminary Edition

Alternative Title

The Mind and The Computer: Problem Solving in the Information Age

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About the Author

Dave Moursund has been teaching and writing in the field of computers in education since 1963. He is a professor at the University of Oregon in the College of Education. He is the director of both a master's degree program and a doctorate program in computers in education.

Some of Dr. Moursund's major accomplishments include:

- Author or co-author of about 25 books and numerous articles.
- Chairman of the Department of Computer Science, University of Oregon, 1969-1975.
- Chairman of the Association for Computing Machinery's Elementary and Secondary School Subcommittee, 1978 - 1982.
- Founder, International Council for Computers in Education, (ICCE) 1979. The name of this organization was changed to International Society for Technology in Education (ISTE) in 1989 when it was merged with the International Association for Computing in Education.
- Chief Executive Officer, ICCE, 1979-1989.
- Executive Officer, ISTE, 1989-present.

Purchasing Information

The prices given below are for prepaid orders and do not include shipping charges. The shipping change on a single copy is $2.85. The book is also available on a Macintosh Microsoft Word disk, and a school site license or a district site license is available. Contact Dr. Moursund for details.

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Preface to 2004 Reprint

I read the "old" manuscript and cleaned up its desktop publication at the end of fall term, 2004. During fall term I taught a one-credit graduate course for preservice and inservice teachers on the topic of roles of Information and Communication Technology in problem solving. A detailed syllabus for this course and no-cost access to my book used in the course are available at http://darkwing.uoregon.edu/~moursund/SPSB/Short-course.htm. Thus, I had the details of that course in mind as I read the old book.

Interestingly, I found only three areas in which the content of the old book was significantly different from the ideas I taught this fall. They are:

1. The old book does not reflect the existence of the Web. It talks about communication via the Internet and about information retrieval from CD-ROM. Thus, it has a focus on use of retrieved information as an aid to problem solving.
2. The old book talks about transfer of learning, but it only covers the "near transfer, far transfer theory." My more recent books, and the course I taught this fall, stressed the "high-road, low-road" theory of transfer of learning. This is a better theory, in that it provides a better foundation for teaching to improve transfer.
3. The old book contains some brain theory, including a statement that the human brain contains 30 to 100 billion neurons and a picture of a neuron. Now, this figure is usually stated as 100 billion neurons. The brain scanning equipment available in the early 1990s looks rather quaint relative to what is now available. Brain science has certainly made a huge amount of progress over the past decade.

As I read the old book, I thought about how educators are faced by the problem of educating children for their future life in a very rapidly changing world. In many fields of science and technology we are seeing a doubling of knowledge in as little as 5 to 10 years. In ICT, we have been seeing a doubling of cost effectiveness in under two years.

However, most of the ideas from the old book are still quite good—indeed, quite up to date. A student who learned these ideas a dozen years ago would still be well served by the knowledge. That is because the focus is on general ideas, rather than on specific details.

For example, consider the idea of learning lower-order knowledge and skills versus learning high-order knowledge and skills. Both are important to a person's education. However, the book has a focus on higher-order—because it is a book about dealing with novel, challenging problems. Students at the middle school and junior high school levels are quite capable of understanding lower-order versus higher-order. This empowers them as they gradually assume more responsibility for their own education.

The idea of a strategy that might problem helpful in solving a problem is fundamental to problem solving. By and large, students are not taught very many strategies that will have long-term value. The book teaches various problem-solving strategies that are apt to last a lifetime.

Problem posing and converting ill-defined problems into clearly defined problems are taught in the book. Again, knowledge and skills gained in this area are apt to last a lifetime.

The book is about problem solving and the increasing roles of ICT in problem solving. The ideas of developing a mental model or a written model of a problem are stressed. But then, these ideas are expanded into a discussion of computer modeling. What does one gain by having an electronic (a word processed) version of a written document versus a hard copy of the document. What are the advantages and disadvantages of each as an aid to representing and solving problems?

This discussion then moves into the issue of what aspects of problem solving can be automated through appropriate use of a computer. One of the advantages of computer modeling is that it fits in well with computer-based automation of a wide variety of problem-solving activities. Today's spelling checker in a word processor is better than what was available in the early 1990s. However, the underlying concept that a word processor can incorporate a spell checker that can help to detect and correct spelling errors has not changed between then and now.

In summary, the "old" book demonstrates that in the early 1990s we knew enough about computers and problem solving to develop and teach a course of enduring value for middle school and junior high school students. By and large, however, few schools have implemented such a course.

David Moursund

December 2004

Preface for Teachers

Specific Intended Audience

Getting Smarter at Solving Problems is specifically designed to be used as a supplemental text in a secondary school Computer Literacy course. When used in that format, the book contains sufficient materials to be used two days a week or part of each day in a semester-length course.

However, *Getting Smarter at Solving Problems* can also be used in a wide variety of other settings. It can be used in a "Modern Problems" class in the social studies; it can be used in a course on problem solving; it can be used in a math course. In all cases the emphasis is on problem solving in general, and roles of computers as an aid to problem solving.

This book is based on the following two premises. The premises are strongly supported by the research literature.

1. Through the appropriate study of the discipline of problem solving, a student can get better at solving both school problems and non-school problems
2. Computers are a powerful aid to problem solving. A student can get better at solving certain types of problems by learning to make appropriate use of computers as an aid to solving the problems.

Computer Literacy Courses

There are many different versions of Computer Literacy courses. A typical Computer Literacy course may focus on just one of the following themes, or it may draw from several of them.

1. Generic tool approaches that focus on use of one or more of the general-purpose tools database, graphics, spreadsheet, telecommunications, and word processor. These tools are interdisciplinary, useful in all levels of schools, and useful both in school and outside of school.

   An alternative is to build a Computer Literacy course around applications software that fits the needs of people in a specific applications area. Music software provides a good example, as does software for use in the fine arts. A Computer Literacy course could be build around a specific piece of desktop publication software or a specific piece of hypermedia software.
2. Computer programming, making use of languages such as BASIC and Logo.
3. A reading, talking, and critical analysis approach. Here the emphasis is on understanding and analyzing the history and current applications of computers, and how computers are affecting our society.

There are many definitions of computer literacy. Generally speaking, computer literacy is a blend of computer science (including computer programming), computer applications, and computers in society (including reading, writing, and talking about computers and their impact on our society). However, there should be one unifying theme: computers are a new and powerful aid to problem solving; they extend the capability of the human mind. Computers can be used to help solve problems in every area of human intellectual endeavor. The capabilities of computers are having a major impact on our world.

Getting Smarter at Solving Problems is designed to provide a unifying and underlying theme of problem solving in a computer literacy course. There is a lengthy Teacher's Manual that accompanies this book. It contains detailed lesson plans and specific suggestions on how to integrate problem solving into each of the general types of computer literacy courses listed above.

Guided Discovery-Based Learning

Getting Smarter at Solving Problems contains an underlying philosophy of discovery-based learning. One reason for this is the general nature of the computer field. The computer field is changing very rapidly. The computers your students will have available in their homes and on their jobs 20 years from now will be a hundred or a thousand times as powerful as the computers they now have available in school. This means that there must be a strong focus on learning to learn and on transfer of learning. A guided discovery-based learning environment contributes greatly to learning to learn, and it facilitates transfer of learning.

Puzzle Problems

Most books on problem solving are full of "puzzle problems." Here is an example.

```
  TWO
+ TWO
 FOUR
```

In this puzzle, each letter stands for one of the digits 0, 1, 2,..., 9. The letter F stands for a digit that is larger than 0. The goal is to find one or more solutions. (Typically, a puzzle problem always has at least one solution. Of course, in the real world there are lots of problems that have no solution.)

For many students, puzzle problems are challenging and fun. Unfortunately, there are two distinct drawbacks to making extensive use of them in instruction.

1. The research suggests that there is relatively little transfer of learning from puzzle problems to other problem-solving tasks. That is, practice in solving puzzle problems helps a student to get better at solving the specific types of puzzle problems being studied. It does not help a student to get better at solving real world problems or even the other types of problems they encounter in school.

2. Many students are turned off by puzzle problems.

Getting Smarter at Solving Problems is quite different from the puzzle problem books. It focuses on the underlying theory and practice of the discipline of problem solving. It focuses on methodologies such as journaling, learning to learn, metacognition, and modeling that cut across all disciplines. It lays foundations that will serve students throughout their lives.

Problem-Solving Software

There are two major categories of problem-solving software that are not discussed in this book. The first type is software specifically designed to help teach problem solving. A number of the educational software publishers make available a wide range of such software. The second type is software specifically designed to help solve certain types of problems, such as math problems. This type of software is of growing importance in each academic discipline. The inclusion of either of both types of software in a course on computers and problem solving is quite appropriate. However, the author of this book decided to write the book to be independent of any specific piece of software or hardware.

Computer and Non-Computer Aids to Problem Solving

The computer is but one of many different powerful aids to problem solving. Reading, writing, arithmetic, speaking, and listening are certainly powerful aids to problem solving.

Most students in your class will have had little or no previous formal instruction in problem solving. Thus, you will be faced by two interrelated tasks.

1. To help your students learn about the general discipline of problem solving. This instruction is oriented toward helping your students get better at dealing with all sorts of problems and using all sorts of aids to problem solving.
2. To help your students learn the capabilities and limitations of computers as an aid to problem solving.

It should be clear that the first task is more general. It does relatively little good to teach the specifics of problem solving in a computer environment if students have no knowledge of general ideas of problem solving. However, it does make sense to use a computer environment as a motivation to study problem solving in general, and then to focus specifically on how computers affect this discipline. That is the design philosophy of this book.

The student text, *Getting Smarter at Solving Problems* , contains only a modest amount of specific focus on computers. However, each topic has been carefully selected to fill a dual role. First, it has been selected because it is foundational within the discipline of problem solving in general. Second, it has been selected because it easily ties in with studying the roles of computers in problem solving.

To a great extent, the *Teacher's Manual*, rather than the student text, provides the bridge between these two areas. This is because the student text is designed to be used in a wide variety of instructional settings. Thus, it is important that you, the course instructor, focus on bridging between problem solving in general, and problem solving within the context of the specific course that you are teaching. The *Teacher's Manual* provides a number of quite specific suggestions in how to do this in a variety of instructional situations.

Don't Expect Miracles

Every student in your class is a smart, problem-solving person. Your students have been developing their problem-solving skills throughout their lives. Your course, and the specific instruction on problem solving based on this book, will be a very modest-sized intervention in the lives of your students. It can make a significant contribution. However, it is a small intervention relative to the total amount of time each student has already spent on learning to solve problems. Getting smarter at solving problems is a life-long task.

Preface for Students

ORGANIZE YOUR THINKING

There is a box like this at the beginning of each chapter. It contains some of the highlights of the chapter. Spend a minute or two reading and thinking about these highlights. Research says that this time will be well spent. It will help you to learn the chapter material much better.

The Preface is about:

- Aids to the human mind.
- Thinking about how you learn.
- Using computers to help you solve problems.

The Computer is an Aid to the Human Mind

This is a book about how computers can help you to solve problems. However, a computer is merely a tool to help your mind. Your mind still has to do most of the thinking!

Thus, this book talks a lot about how your mind works. It talks about how to help your mind get better at solving problems. If you practice the ideas in this book, you will get a lot better at solving problems in school and outside of school.

Other Aids to the Human Mind

There are many aids to the human mind. Reading, writing, and arithmetic are all very important mind aids. They help you to solve problems that you could not solve just using your mind all by itself.

Reading is especially important. If you can read this book, you can read well enough so that you can learn new things by reading. Being able to read opens up a whole new world. It allows you to solve problems by reading about how others have solved the problems.

Another important mind aid is learning to learn. There are lots of ways to learn new things. As you know, different people learn in different ways. Some people learn best by "seeing"—by receiving information through their eyes. Others learn best by "hearing"—by receiving information through their ears. Still others learn best by "physically doing"—by being physically engaged in carrying out the processes to be learned.

These differences in how people learn make it difficult for a teacher to teach only in the way that seems best for you. This means that it is important for you to learn how you best learn. You must become responsible for your own learning.

Also, the way you learn best may vary with different things that you want to learn. Think about sports, and how you get better at sports. Think about how you learned to make friends and how you get better at making friends. Think about how you learned how to read, and how you get better at reading. Think about math classes, and how you get better at solving math problems.

Now be aware of what you just did. You were thinking about how you learn. You are a unique person. You are different from every other person. You are the only person who can really know yourself. You are the only person who can really learn how you learn best.

One of the most important learning things that you can learn is how to learn. How does your mind work as it learns new things? What helps it to learn rapidly and well? What helps it to remember important new ideas? What helps it to get better at solving problems?

You learn many new things everyday. This means that you get a lot of practice in learning. Some of this learning occurs without much effort on your part. For example, you see and hear a television ad, and you learn a little about the product being advertised. You hear a friend using a new word, and you automatically start using that new word.

But other learning takes more effort. Over the centuries, humans have accumulated a great deal of knowledge and wisdom. Many brilliant thinkers, such as Marie Curie and Albert Einstein, have contributed. There is lots to learn.

One reason we have schools is to make it easier for people to learn. One goal of this book is to help you get better at learning. There is a simple way to get better at learning. As you learn, think about learning. Examine your own personal learning processes. Figure out what works best for you. Experiment. Try different approaches. Gradually you will get better at learning.

You Will Need a Journal

Early explorers kept journals or diaries in which they wrote about their travels. As you read this book, think of yourself as an explorer. You are exploring the content of this book. You are exploring your mind and how it reacts to the book. You are exploring computers and how they can help you solve problems.

Many of the activities in this book ask you to write in a journal. You will need a bound book, such as a spiral bound notebook, to use as a journal. Please get yourself a journal book before starting to read the first chapter. Keep it with this book, so that you will have it when you need it.

Educational researchers have thought a lot about how to help students learn better. They have decided that writing in a journal helps most students learn better.

This seems to be true in every school subject. And it works well for both young people and adults. Don't be surprised if you see your teacher doing journaling!

What This Book is About

This is a book about human problem solving. It places a major emphasis on roles of computers as an aid in problem solving. Computers are a very powerful aid. Computers are especially useful in solving the types of problems that you study in school. You can get much better at solving many types of problems by learning to use computers as an aid to problem solving.

This book will help you get better at problem solving. However, don't expect any magic. It has taken your entire life to get as good at problem solving as you are now. This book will help you get better. But getting better at problem solving takes time and effort.

PREFACE SUMMARY

There is a box like this at the end of each chapter. It contains a summary of a few of the key ideas in the chapter.

The purpose of the Preface is to get you started in thinking about what this book is about. Some key ideas include:

1. A computer is a powerful aid to the human mind. Reading, writing, and arithmetic are also powerful mind aids.

2. It is important for you to learn how you best learn.

3. By studying and practice, you can get better at problem solving.

Chapter 1

Introduction to This Book

ORGANIZE YOUR THINKING
You live in a complex and rapidly changing world. One purpose of schools is to help you learn to cope with the types of problems you will encounter when you become an adult. This means that you need to: • Learn how to learn. • Get better at solving problems. There are many ways to get better at problem solving. One way is to write ideas in your journal that occur to you as you read.

Some Aids to Learning

If you skipped over the Preface for Students, please go back and read it. It tells you what this book is about. It lists several of the key ideas. It is important that you think about these ideas before reading the rest of the book. This will help you to learn more and better from this book.

Also, did you think about the ideas in ORGANIZE YOUR THINKING? This brief introduction to the chapter is called an **advance organizer**. Its purpose is to get your mind to start thinking about the key ideas in the chapter. Research says that use of an advance organizer will likely help you to learn better. Many teachers and books make use of advance organizers.

This book contains a Glossary. When an important new term, such as advance organizer, is first discussed, it is given in bold face. The Glossary contains definitions of these terms. It is very important that you practice using these new terms. Use them in your talking and in your writing. Make them part of your working vocabulary. This will help you to learn the important ideas in this book.

Writing in Your Journal

This book is designed to help you learn some very important ideas. Probably you have heard the expression:

You can lead a horse to water, but you can't make it drink.

What do you think this expression means? How does it relate to reading and using this book?

Before going further in this book, get your journal started. Write your name in the journal. Number the first 20 pages or so. Use both sides of the pages. Write the current date on the first page.

Each day you use this book, draw a line across the page below the previous writing in your journal. Skip a few lines and write the date. Remember to make use of the both sides of the pages.

✍✍ Note: The hand and pencil symbols are a suggestion that you **may** want to write an answer in your journal. In some places in the book we will make a **very strong suggestion** that you write in your journal. Then we will give you a suggested title line for your journal entry.

Begin ✍✍ (You may want to write in your journal.)

Did you think about answers to the questions about the horse and water? Did you think of more than one possible for each question? If not, please read the questions again. Think about several answers to each question. You may want to write them in your journal. You may want to draw a picture of a horse and water in your journal.

End ✍✍

You can learn a lot from this book. But to learn from this book, you will need to think about what you are reading. You will need to practice the ideas. It will help you a lot if you write down some of your thoughts.

Writing and talking are closely related to thinking. To write or talk clearly, you must be able to think clearly. Practice in writing and talking clearly will help you get better at thinking clearly.

As you read, make notes about the ideas that seem most important to you. If a picture forms in you head, draw the picture in your journal. When the book asks you a question, jot down an answer in your journal. If you think of a question you would like to ask your teacher, write it down. Maybe you will think of a question that you want to think about some more. Write it down, so that you can come back to it when you have more time.

The World is Changing

The world you live in is a lot different from the world your grandparents lived in when they were young. When your grandparents were young, they did not have color television (no MTV!), jet planes, or vaccines to prevent polio. They did not have fast food restaurants, cassette tape recorders and VCRs. They did not have

communication satellites, fiber optics, and cellular telephones. They did not have computers and video games.

You live in a rapidly changing world. It is called the **Information Age** because so many people have jobs working with information. (Remember, you can find a definition of Information Age in the Glossary. Read that definition now. It contains some ideas not given in this chapter.)

Your teacher is a person who works with information. All people who are using computers are working with information. A computer is an information processing machine. It can deal with information that can be represented using words, pictures, and sounds.

Of course, not all people have jobs working with information. Many people work with machines used to manufacture cars, refrigerators, television sets, and so on. At one time more than half of all workers in the United States had such jobs. That was called the Industrial Age. But now less than one-fifth of the jobs in the United States are of that sort. This number is still decreasing.

Many people have service jobs. They work as clerks in a store, tellers in a bank, nurses, truck drivers, and so on. They need to be good at working with other people. Often they make use of electronic machines, such as a cash register or a computer, to help them do their work. The number of people doing this type of job is increasing rapidly.

By the time you get to be an adult, there will already be many changes from the way things are now. There will be new types of music. There will be new forms of entertainment (3D video games and television?). There will be new medicines, new foods, new forms of clothing. There will be many kinds of jobs that do not yet exist. Computers will help do many different jobs.

Teachers know that you (and they) live in a rapidly changing world. They want to help you learn to deal with change. Schools are designed to help prepare you for the future.

Begin ✍✍ (You may want to write in your journal.)

Think about some changes in the world during the past few years. Make a list of some of these changes. Put a check mark beside each of these that strongly affects you.

End ✍✍

Learning to Think

Schools have many goals. Two of them are:

1. To help students learn some basic information and develop some basic skills.
2. To help students learn to think and solve problems using basic information and skills.

This may seem simple. First, you need to learn some basic information and you need to gain some basic skills. But perhaps these thoughts are going through your head:

> I wonder what information is important enough to learn? For example, is it important to memorize the name of each state, where it is located on the map, and each capital city? What if I forget some of what I am supposed to have memorized? Is it all right to look up stuff in a book instead of memorizing it?
>
> What skills are really important? I understand the need for reading, writing, and arithmetic. Is having neat handwriting an important skill? Is being able to play a piano or sing on key an important skill? Is knowing how to touch type fast and accurately an important skill?

Second, you need to learn to think and solve problems using your basic information and skills.

> What does "to think" mean? How can I tell if I am good at thinking? Is it possible to get better at thinking? How are thinking and problem solving related? Can computers think?

As you can see, these two goals are not so simple. Let's give some examples. First, let's consider an example having to do with spelling and writing. Spelling requires memorization. You must memorize how to spell specific words and rules to help you spell words. Writing involves thinking. You must learn to organize and express your thoughts.

Begin ✍✍ (You may want to write in your journal.)

Now, what is the best way to get better at writing? Should you spend your time memorizing how to spell more and more words? Or, should you spend your time learning to organize and express your thoughts? Which is better for you? Do you think that the answer is the same for every student?

Probably you have used a word processor on a computer. Most word processors have a spelling checker that can help find misspelled words. Suppose that whenever you needed to write, you could use a word processor with a spelling checker. Do you think this might change how much time you spend memorizing how to spell words?

End ✍✍

For a second example, we will look at math. In your math classes you have memorized a large number of math facts. Probably you have memorized number facts such as the times table:

x	1	2	3	4	5	Etc.
1	1	2	3	4	5	
2	2	4	6	8	10	

3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Etc.

You have memorized how to add up a column of numbers, how to do subtraction, how to multiply numbers, and how to divide numbers. You have spent many hours practicing these skills.

Begin ✍✍ (You may want to write in your journal.)

But a hand held calculator can help do addition, subtraction, multiplication, and division. Think about that for a minute. It took you a long time to learn how to do pencil and paper long division. It takes only a few minutes to learn how to use a calculator to do long division. Calculators are cheap and readily available. Why should you use your school time and brainpower learning to do long division by hand?

End ✍✍

This is not an easy question. There are other questions like it that are even harder. A computer can solve many different kinds of problems. A computer can solve many of the types of problems that you study in school. Suppose a computer can solve a type of problem that you are studying in school. What should you learn about solving the problem?

As you think about this question, you should be aware that new and better computers are being developed. That is, computers are getting more and more capable. Should you spend time in school this year learning to do something that next year's computers will likely be able to do?

These questions are very important. Please spend some time writing about them in your journal.

Begin ✍✍ (Please write in your journal.)

Make a title for this journal entry. Your title might look like this:

LEARNING ABOUT PROBLEMS THAT COMPUTERS CAN SOLVE

Note: You will want to label your journal entries in a clear fashion. One way to do this is to begin each entry with a title line. When we strongly recommend that you write in your journal, we will suggest a title line for you. But it is all right to make up your own title lines.

You may also note that this question has no right answer. You are to give your own opinion. You should give arguments to support your opinion.

End ✍✍

Problem Solving

Educators know that the best way to prepare you for the future is to help you get better at learning, thinking, and problem solving.

Once you get good at learning, you can learn the new things that the future will bring.

Once you get good at thinking, you will be able to think clearly about the new things that the future will bring. Chapter 6 contains many ideas on how to get better at thinking. You may want to look at it right now. Remember, you are in charge of your own learning. There is no rule that says a book must be read from front to back!

Once you get good at solving problems, you will be able to solve the new problems that the future will bring. There are many ways to get better at solving problems. One way is to learn the **basic skills**:

1. Learn to speak and listen.
2. Learn to read and write.
3. Learn to make use of arithmetic and mathematics.

You know that schools spend a lot of time on these basic skills. Every educator knows that these are important.

People have developed a number of other aids to problem solving. This book spends a lot of time talking about two types of aids–strategies and tools.

1. **Strategies–plans of attack**. A **strategy** is a general way to try to solve problems. It is easy to learn some strategies that will help you to solve many different problems. A few are listed below. Many more are discussed later in this book.
   A. Break big problems into smaller problems. (The smaller problems may be much easier to solve.)
   B. Draw a picture or a diagram to help you see what is happening in the problem. (The human mind is very good at dealing with pictures.)

C. Use brain storming, either by yourself or in a group. (This is a good way to get some ideas about a hard problem.)

D. Make use of reference books. (A good way to solve a problem is to look up how to do it in a book.)

E. Learn to use a computer. (A computer can solve or help solve many different kinds of problems.)

2. **Tools that help solve problems**. People have developed a wide variety of tools to help them solve problems. Several examples are given in the next two paragraphs.

Throughout recorded history, people have been developing tools to help them solve problems. First they developed tools to extend the capabilities of the human body. Examples include the club, spear, knife, hammer, plow, microscope, and telescope.

Then they developed tools to help in communication and transportation. Communication aids include the telegraph, telephone, and two-way radio. Transportation aids include the bicycle, train, car, and airplane.

More recently, people have developed the computer. The computer is a general-purpose tool designed to extend the capabilities of the human mind. It is useful in every subject that you study in school. It is an everyday tool in many jobs that adults do. Thus, it is very important that you learn how to use a computer as an aid to problem solving.

Begin ✍✍ (You may want to write in your journal.)

Think about tools that you use. You use lots of different tools. A comb and a toothbrush are tools. Make a list of tools that you often use. For each tool, tell what problem it helps you to solve.

End ✍✍

Goals of This Book

This book has two specific goals:

1. To help you get better at solving problems.
2. To help you learn some of the roles of computers as an aid to solving problems.

These are big goals, and this is a relatively little book. As you read this book you will learn some basic ideas. But you will need to practice these ideas if they are going to make any difference in your life. You will need to practice whenever you run into a problem. This means you will need to practice when dealing with your friends and other people, when you are at home, and when you are at school.

Different "Levels" of Thinking Skills

There is quite a difference between learning some basic facts and learning to think using the facts. See how well you can do on the following four-question quiz.

A1. Columbus discovered America in the year ____.

A2. The Earth orbits about a star we call the ____.

A3. The name of the first president of the United States is ____.

A4. The name of the state located just to the north of Oregon is ____.

Each of these questions asks you to provide a fact—a piece of information—for an answer. It is relatively easy to teach facts and to test whether students have memorized the facts being taught.

Now consider the following questions:

B1. Columbus discovered America in the year 1492. What was he trying to accomplish on his historic voyage, and why was it important to try to accomplish it?

B2. The Earth orbits about a star we call the sun. How do we know this? (You might want to describe several different scientific experiments that could be used to prove the assertion.)

B3 The name of the first president of the United States is George Washington. What was the process that led to his becoming president, and why didn't he become the king of the United States?

B4. The name of the state located just to the north of Oregon is Washington. Give some reasons why this geographic region of the United States is divided into exactly two states. (Why not just one, or why not more than two? Remember, the Oregon Territory was much larger than the current state of Oregon.)

Notice the big difference between the first group of questions and the second group of questions. The first four questions all ask for facts. To answer the questions, one must have memorized the facts. The questions do not test for relationships among these facts and related facts. The questions do not test for understanding of the meaning or use of the facts. These are examples of **lower-order thinking skill** questions.

The typical human brain is able to memorize and rapidly recall many thousands of facts. Some people are much better at this than others. Some of the very best memorizers get to be on television quiz shows. Viewers are impressed by their powerful abilities at immediate recall of isolated facts.

Of course, some people are not very good at memorizing facts. In any case, it takes a lot of time to memorize a large number of facts. Also, the brain has a natural tendency to gradually forget memorized facts that it does not use frequently. Books and computers are far superior to people at memorizing and not forgetting. Our school systems long ago decided that it is far better to take time away from memorizing and use it to teach reading. With reading skills, one can make use of books to look up facts. Similarly, many schools are now teaching students to make use of computers to store and look up facts.

The second group of questions relate to the first group. Answering them requires making use of a variety of facts. But they can be answered by drawing upon quite a

wide range of facts. Failure to recall some specific fact is not likely to stand in the way of providing a good answer to a question. Answering these questions tends to require understanding of principles underlying the facts and relationships among facts. These questions test **higher-order thinking skills**.

There is one subtle but important point. If one is given the questions in advance, then questions B1-B4 become merely somewhat more complex examples of lower-order skill questions. A student can look up or ask a friend the needed facts, the underlying principles, and relationships among the facts. An answer can then be memorized for later regurgitation.

The same general statement holds for problem solving. A person has a problem when they encounter a situation in which they are unable to immediately achieve a desired goal. If the same problem situation occurs over and over again, it may well be appropriate to memorize how to achieve the desired goal, and to practice the necessary steps so they represent no obstacle. Then the problem is no longer a problem, since there is no barrier to immediately achieving the desired goal.

Education for problem solving would be simple if the typical person only encountered a quite small number of problems as they functioned in our society. The person could study each type of problem in advance, memorize the steps needed to solve each type, and practice them to a satisfactory level. Unfortunately, the number and variety of problems that a person is apt to encounter is essentially unlimited. It is not possible to function effectively based purely on memorized solutions to frequently occurring problems. A good memory is useful. But even more useful is good skill at dealing with new and unfamiliar situations. That is what problem solving is all about.

Learning From the Activities at the End of the Chapter

A few people can learn new ideas just by reading a book. But most people need to practice the ideas if they are going to learn them. That is why teachers give assignments.

There are a number of activities at the end of each chapter. Some just ask you to do some thinking. Others ask you to talk to some of your friends and other people. Still others ask you to do some writing. In each case you should think about why the activity is included in the book. If you can figure out some good purposes for an activity, you will learn more from doing the activity.

You might ask, "Why not just tell us the purpose of an activity?" The answer is, you will learn more if you figure it out for yourself. Most likely you will figure out purposes that are important to you. You will figure out purposes that the author did not think of. The "figuring out" process will help you to get better at thinking and problem solving.

All of the activities in this first chapter can be done mentally, just by making up answers in your head. All can be done by talking with other students in your class, sharing answers you have thought about. Thinking and talking are good ways to

learn. All can be done by writing in your journal. Writing is a very powerful aid to learning.

It is particularly important that you do the first activity as a journal writing activity. Each chapter contains a similar activity. The second activity in each chapter is a "talking" activity. You can learn a lot by talking about the ideas that you want to learn. The third and fourth activities ask you to make up some short quizzes and try them out on others in your class. You can learn a lot by figuring out what you think are the important ideas that a quiz might cover.

CHAPTER 1 SUMMARY
Here are four good ways to get better at problem solving: 1. Learn reading, writing, and arithmetic. 2. Learn a number of general-purpose strategies for solving problems. 3. Learn to use tools, such as the computer, that help solve problems. 4. Practice solving problems.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how the world is changing. Perhaps you thought about how much you are learning in school—and that there seems to be an awfully lot to learn. Perhaps you thought about ways in which you are already very good at problem solving. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.
    1. Make a title for this journal entry. Your title might look like this:

       _____

       CHAPTER 1 ACTIVITY 1

       AN IDEA I HAD WHILE I WAS READING CHAPTER 1
    2. Write down and explain the idea.
    3. Explain why the idea interests you. Why did you remember this idea?
    4. How does this idea relate to things that you do outside of this class?
    5. What else do you think about when you think about this idea?
2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

advance organizer

basic skills

higher-order thinking skill

Information Age

lower-order thinking skill

strategy

3. Make up a short quiz of lower-order thinking skill questions for this chapter. Include correct answers with your questions. Try out your quiz on two students in your class. Here are three examples of lower-order thinking skill questions.

   A. When did the Information Age begin in the United States? (If your answer is within five years of the exact date, it will be considered to be correct.)

      Answer: 1956

   B. Name at least three tools that people use to help solve transportation problems.

      Answer: Airplane, bicycle, car, skateboard, train.

   C. True/False A *strategy* is a plan that will solve any problem.

      Answer: False.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. Think about possible answers. Try out your quiz on two students in your class. Here are two examples of higher-order thinking skill questions.

   A. In an Information Age, more people have information and service jobs than have manufacturing jobs. How does this affect what students should learn in school to help prepare them for life in an Information Age society?

   B. A steam engine is a tool that helps the human body do physical work. A hand held calculator is a tool that helps the human mind do mental work. Give two more examples of each of these kinds of tools. Then discuss how the development of tools that aid the human mind affects education.

5 You know that it is important to learn how to write. People have developed various tools to help them write. Examples include the typewriter, ballpoint pen, and word processor. In what ways is a word processor a more powerful aid to writing than a ballpoint pen or a typewriter? In what ways is it not as good?

6. One part of this chapter talks about memorizing facts and learning to think using the facts. Both are important. Which seems more important to you? (Explain why.) Which are you better at?

7. There are lots of ways to get better at problem solving. This chapter suggests several. Here are a few more:

A. Practice making up problems.

B. Learn a lot about a subject–this will help you in solving problems in that subject.

C. Develop a positive attitude and self confidence.

D. Learn to work hard and to keep trying.

Add several more items to the list. Then decide which ones are best for you. Are these same ones also best for other people you know? If you were going to pick just one to really get better at, which one would you pick? Why?

8. Think of someone you know who is a very good thinker. How do you know this person is a very good thinker? (How can you tell? What does this person do that helps you know they are a good thinker?)

Chapter 2

You Are A Smart Person

ORGANIZE YOUR THINKING
The ability to think before you act is very important in solving problems. Most people are good at considering alternatives. This chapter is about: • What does it mean to be smart? • Thinking about your own thinking. • Thinking about what kinds of problems are easy for you.

You Are Smart

This book can help you get smarter. We will begin this chapter with a short quiz. Most likely you will do really well on this quiz. This will show that you are quite smart. It will show that you are smart enough so that this book can help you get smarter.

You will need to use your journal. Start by thinking about some things that you do for fun outside of school.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   FUN THINGS THAT I MAY DO AFTER SCHOOL TODAY

2. Make a list of three different things that you may do after school this afternoon or evening that would be fun.
3. Next, underline the one of these three things that you feel would be the **least** fun.
4. Finally, write down a possible replacement for the item that you have underlined. Write down something that you feel would be more fun and that is not already on your list.

End ✍✍

That's it. That's the whole quiz. You passed if you were able to do what it asked you to do. Did you think that this was a hard quiz? What was hard about it? What was easy about it? Did the idea of taking a quiz scare you?

To pass the quiz, you had to know how to read, write, and follow directions. You needed to think about what might happen in the future. You needed to create an alternative to what might happen. A person who can do all of these things is quite smart.

What Does It Mean To Be Smart?

It is not easy to define the word *smart*. It is even harder to make up a good test to see how smart someone or some creature is. Perhaps you have a pet cat or dog that seems rather smart to you. Do you think a cat or dog can plan alternative activities about what it might do later in the day? How would you test this?

Begin ✍✍ (You may want to write in your journal.)

Respond to some of the questions about being smart. How can you tell if a cat is smart? Do cats plan their day in advance? How could you tell? Are cats smarter than dogs? How could one test your answer to see if it is correct?

Make up a definition of what it means to be a smart person. Remember, you are a smart person. You should satisfy your own definition of being a smart person.

End ✍✍

In this book we will use a simple definition of a **smart person**.

> You are a smart person if you can understand and can solve the problems that you encounter. The more of these problems you can solve, the smarter you are. A smart person can solve lots of different kinds of problems. A smart person can solve hard problems and can learn to solve new problems.

This definition says that how smart you are is how good you are at solving problems. Researchers have discovered lots of ways to help people get better at solving problems. This book contains many of their ideas. You will find that these ideas are easy to learn and easy to use. Thus, this book will help you become smarter.

Sometimes the problem you must solve is what decision to make. "What should I wear today?" "What should I have for lunch today?" What book should I read for my social studies project?" In decision situations, you can think about different possibilities. You can imagine what might happen from each decision. You can make a decision on what outcome seems best. This is an important type of problem solving.

Different Kinds Of Problems

There are many different kinds of problems. For example, there are problems in dealing with your friends. There are problems about how to get to some place in town and home again without getting lost. There are problems that have to do with

doing well in sports. There are problems that have to do with school subjects such as math, science, reading, and writing. There are problems that have to do with playing games such as Monopoly and chess. There are problems in dealing with technology, such as telephones, stereos, and computers. There are problems in dealing with the types of change going on in our Information Age society.

A person might be very good at dealing with one type of problem and not so good at dealing with another type of problem. For example, a person might be very good at solving chess problems and not very good at dealing with people problems. A person might be very good at dealing with school problems and not very good at dealing with problems outside of school. A person might be very good in music and not so good in sports.

Think about this for yourself. Are you better at solving "school" problems or at solving "people" problems? Are you good at finding your way to new places and not getting lost? Are you better at music, or sports? Are you good at being popular? Are you good at organizing your activities and keeping your locker clean and neat?

Remember, writing in your journal is very important. You will learn much more if you regularly write in your journal. As you write, think about what you are writing. Clear thinking and clear writing are closely connected!

Please do the following journal writing activity. You will use the results later in this chapter and in the next chapter.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   IMPORTANT PROBLEMS THAT ARE EASY FOR ME

2. Write down a type of problem that is important to you and that you are good at solving. One way to do this is to first think of a specific example of a problem that you have solved. For example, maybe you saved money to buy a neat new outfit. Then think of the general problem that this suggests. For example, perhaps you are good at solving the general problem of budgeting your money.
3. Now think of another type of problem that you are good at solving. Pick one that is a whole lot different from your first type of problem. For example, you might think about a new friend that you made yesterday. This would help you to think about how good you are at making new friends. Being good at making new friends is a lot different from being good at budgeting your money.

End ✍✍

Thinking About Thinking

Educators have done a lot of thinking about how to help students get better at solving problems. They have come up with many good ideas. Schools are designed to help students learn some of these ideas.

One of the very best ideas is thinking about thinking. Remember the quiz at the beginning of this chapter? In it you had to think about what you might do after school and this evening. You then had to think about which of these things would be the least fun. You were thinking about thinking!

Thinking about thinking is so important that there is a special word for it. It is called **metacognition**. If you practice thinking about thinking—if you practice metacognition—then will get better at thinking and problem solving.

In the journal writing activity, IMPORTANT PROBLEMS THAT ARE EASY FOR ME, you were thinking about kinds of problems you are good at solving. You were thinking about your own problem-solving skills. You were doing metacognition. Look back at what you wrote in your journal. Think about what you wrote. Do so more metacognition.

When you are listening to the teacher talk, your mind sometimes wanders. You begin to think about something else, such as meeting a friend for lunch. Then you think to yourself, "I wonder what the teacher said that made me think about meeting my friend for lunch?" You are thinking about your own thinking. You are doing metacognition.

Let's practice doing metacognition. This is a journal writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   PRACTICE IN METACOGNITION

2. Go back and read your journal entry with the title IMPORTANT PROBLEMS THAT ARE EASY FOR ME.
3. How are these problems alike? Make a brief list of how these problems are alike.
4. How are these problems different? Make a brief list of how these problems are different.
5. Now write several sentences about why these problems are easy for you to solve.

End ✍✍

CHAPTER 2 SUMMARY

Metacognition–thinking about thinking–is very important. You can think about your own thinking. This is one way to get better at solving problems. Some other key ideas in this chapter include:

1. You know some types of problems that you are good at solving.

2. You can think about why some problems are easier for you than other problems.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about why are good at some things and not so good at others. Perhaps you thought about daydreaming and whether daydreaming is like metacognition. Perhaps you thought that thinking about thinking makes your brain dizzy. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 2 ACTIVITY 1

   AN IDEA I HAD WHILE I WAS READING CHAPTER 2

   2. Write down and explain the idea.
   3. Explain why the idea interests you. Why did you remember this idea?
   4. How does this idea relate to things that you do outside of this class?
   5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Here are a few of the things you might talk about. Why did you select the topic?? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary. Also, look back at the list of new terms given in the previous chapter. Use some of them in your discussion.

   metacognition

   smart person

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Is a book smart? In some sense, a book "knows" a lot of facts. A large dictionary "knows" the spelling and definitions of a lot of words. Write several paragraphs in your journal about the question, "Is a book smart?" You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 2 ACTIVITY 5

   IS A BOOK SMART?

   2. Write a paragraph that argues that a book is smart.
   3. Write a paragraph that argues that a book is not smart.
   4. Write a paragraph that contains your own, personal conclusions.

6. Is a machine smart? For example, think of an elevator. As people get on, they push the button of the floor where they want to get off. The elevator is "smart" enough to arrange these requests in a logical order, and then to stop at these floors.

   Or, consider a calculator. If you want to multiply two numbers, you just key the numbers in and the calculator "knows" how to do the multiplication. It can do it rapidly and without error. If a person can do multiplication rapidly and without error, we say the person is "smart" at doing multiplication.

   Write several paragraphs in your journal about the question, "Can a machine be smart?" You might want to use the outline given below.

   1. Make a title for this journal entry. Your title might look like this:

      _____

      CHAPTER 2 ACTIVITY 6

      CAN A MACHINE BE SMART?

      2. Write a paragraph that argues that a machine can be smart.
      3. Write a paragraph that argues that a machine cannot smart.
      4. Write a paragraph that contains your own personal conclusions.

7. In journal writing activity, IMPORTANT PROBLEMS THAT ARE EASY FOR ME, you gave some examples of problems that were easy for you to solve. Here the task is to think of examples of problems that are hard for you.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 2 ACTIVITY 7

   IMPORTANT PROBLEMS THAT ARE HARD FOR ME

   2. Write down a general type of problem that is important to you and that you are not good at solving. One way to do this is to think of a specific example of a problem that you tried to solve but did not solve. For example, you may have bought junk food and gone to a movie with the money you were saving to buy a new sweater. Then figure out what the general problem is. In the example here, perhaps the general problem is that you are not good at saving money.
   3. Now think of another type of problem that you are not good at solving. Pick one that is a whole lot different from your first type of problem. Perhaps the problem is that you are not good at singing on key.

8. This activity assumes that you have done Activity 7 given above. In that activity you thought about two types of problems that are hard for you. Here we want you to think about what makes these types of problems hard for you.

   1. Make a title for this journal entry. Your title might look like this:

      _____

      CHAPTER 2 ACTIVITY 8

      METACOGNITION ON HARD PROBLEMS

      2. How are your two problems alike? Make a brief list of how the problems are alike.
      3. How are your two problems different? Make a brief list of how the problems are different.
      4. Now write several sentences about why these problems are hard for you to solve.

9. Write on the topic of argument for and against the statement that a person gets smarter by going to school. We suggest that you do this as follows.

1. Start your journal entry with the title:

   _____

   CHAPTER 2 ACTIVITY 9

   GETTING SMARTER BY GOING TO SCHOOL

2. Give arguments that you believe show that one can get smarter by going to school.
3. Give arguments that you believe show that one cannot get smarter by going to school.
4. Summarize your personal opinion. Base this on how you feel and think about the ideas you have written.

If you have enough time, also write on:

5. Some way to gather more evidence that would support 2.
6. Some way to gather more evident that would support 3.

10. A good thinker can argue both sides of a question. A good thinker can understand another person's point of view. You can get better at thinking by practicing arguing both sides of an issue.

    Think about the last time you had an argument with someone. Make a list of arguments for both sides. Try really hard to make a good list for the other person! (You may want to do this as a journal writing exercise. Or, you may want to do it on scratch paper and then throw the paper away.)

Chapter 3

What Is A Problem?

ORGANIZE YOUR THINKING
This chapter contains a four-part definition of *problem*. This definition is used throughout the rest of the book. A starting point in solving a problem is to gain a clear statement of the problem. This chapter will give you practice in: • Metacognition, to understand the meaning of *problem*. • How to deal with problem situations that are not clearly defined problems. • Brainstorming, a useful strategy in dealing with problem situations.

What Does the Term *Problem* Mean to You?

The first two chapters talked about problems and getting better at solving problems. You thought about examples of some types of problems that you find easy to solve. It is clear that you sort of understand what the term *problem* means. You have no trouble using it correctly when you talk and write. But, do you think that the term *problem* means the same thing to all people?

This is important. Suppose that the term *problem* has a quite different meaning to you than it does to the author of this book. Then you and the book will be at odds. You will be expecting things that the book is not intended to do. In a similar manner, suppose that the term *problem* means different things to your teachers than it does to you. This will cause trouble when they try to help you learn about problem solving.

This chapter has one main goal. The goal is to help you learn the definition of the term *problem* as it is used in this book. It is the definition used by most authors of books on problem solving. The rest of this book assumes that you understand and use this definition.

What is Your Definition of a Problem?

Pat is a student in a school like yours. Think about Pat encountering a number of **problem situations** during the day. These are situations that concern or disturb

her. They are situations that Pat might try to do something about. She might do something that would change the situations.

But in these problem situations Pat does not see an immediate course of action. She doesn't know what to do that will resolve the situation. Pat would need to do some thinking in order to decide on a course of action.

1. Pat wakes up in the morning and remembers that it is a school day. Pat thinks, "Most of my clothes are dirty. What should I do?"
2. At breakfast, the television set is on. Pat hears the announcer talking about an African country. "The situation is grave. It is reported that 5,000 children are starving." Pat finds that it is hard to eat while thinking about these starving children.
3. Pat enters the front door of the school just as the bell for first period rings. Pat thinks, "If I go to my locker and get the books for my first class, I'm going to be tardy. What should I do?"
4. The teacher in Pat's second period gives a very long homework assignment. Pat thinks, "I don't have time to get it done during study hall. What shall I do?"
5. In the science class, the teacher tells the students to do the first three problems on page 98. Pat looks at the first problem and thinks, "I don't understand this problem. What am I going to do?"
6. In talking to a close friend, Pat says, "This guy wants to meet me at the game tonight. What do you think?"
7. Pat's social studies teacher is talking about drunk driving. The teacher says, "Last year in this country about 25,000 people died because of drunk drivers." Pat thinks about her older brother's friend who drinks and drives. She feels scared.

As you read about Pat's problem situations, they may suggest some of the kinds of problems that you have. Think about the kinds of problem situations you encounter day to day. In what ways are they alike? In what ways are they different? Remember, this type of thinking is called metacognition. It would be best if you do it as a journal writing activity. In this activity you will write a definition and share it with others in your class.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

_____

MY DEFINITION OF PROBLEM

2. Write down what the term *problem* means to you. Write your definition so that other students in your class will understand what you mean.
3. Next, get together with two or three other students. Each student is to read their definition out loud and explain what they mean.
4. Then your whole group is to work together to make up a definition. Make one that you can all agree on. It should include all of the key ideas that each group member has thought of. Write this definition in your journal. Or, your teacher may provide each group with a large sheet of paper and a marking pen. Then you can write your group's definition on the paper and post it for the whole class to see.

End ✍✍

The above exercise has three purposes. First, it gives you a chance to clarify your thoughts on what *problem* means to you. Writing is a very important aid to problem solving. Writing **helps** your brain to think. Writing **requires** your brain to think. It helps you to organize and clarify your thoughts on a problem.

Second, it gives you a chance to work with other students. You get to hear what they are thinking. You learn how their minds work. It is interesting to learn that people think in different ways. There is no one "right" way to think.

Third, it gives you a chance to work in a group to accomplish a task. Working together in groups is a very important approach to solving problems. Also, working in groups is a good way to learn. It is called **cooperative learning**. Working in groups is so important that we will suggest a number of group activities in this book.

By now you should realize that it is not easy to give a good definition of the term *problem*. In this next section we will study a sample problem. We will point out some of its key features. These key features are part of every problem.

Halloween Costume Day At School

Terry is a student in a school like yours. Here is a problem situation that Terry has:

> Next Thursday is Halloween. The students and teachers have talked about it. They have decided to make it a costume day. Everybody is encouraged to dress up. Some students have indicated they will dress up as a Wizard of Oz character. Some will be characters from other books. Others will wear masks or funny makeup. The students and teachers suggested that no one should spend more than $12 on their costume.

Terry had to decide what to do about Halloween day at school. She is very careful and methodical in her thinking. She knows a lot about problem solving. She organized her thinking into four parts and wrote notes to herself about each part. This is what she wrote:

1. **The given situation**: Halloween is next Thursday. This is a regular school day, but it will also be costume day. Many students and teachers will be wearing costumes.
2. **My goal**: I must get a costume to wear to school next Thursday.
3. **Resources and Restrictions**: I can think of a number of things that I might do. For example:
   A. (A Resource): My mother has some old clothes she wore when she was young. Maybe some of these old things would be useful to me.
   B. (A Resource and a Restriction): I have about $10 saved up. This is less than the $12 maximum that a person is allowed to spend. I could use the money to buy a part of a costume.
   C. (A Resource): I have a costume that I used in a parade a few months ago. It still fits.
   D. (A Resource): I have several friends who might loan me a costume.
   E. (A Resource): I am creative. I might make a costume.
   F. (A Resource): I am a good thinker. I might use two or more of the above ideas together.
   G. (A Restriction): But I don't want my costume to be too elaborate.
   H. (A Restriction): I don't have much time to work on getting a costume.
4. **Importance to me:** Dressing right for Halloween costume day is very important to me. All of my friends will be wearing costumes. I want to be part of the group. I don't want to stand out as being different.

All of Terry's writing didn't solve the problem. But it organized the problem into four parts. The problem is carefully defined. Each of the four parts seems clear to Terry. This is called **problem posing**. Problem posing is making up a problem. Problem posing requires very careful thinking. It is the starting point for resolving a problem situation.

In some sense, each person in the school is faced by the same problem situation. Each person must decide what to wear on Halloween day. But the details are probably different for each person. The same problem situation (Halloween costume

day) creates different problems for different people. Each person must do their own problem posing.

Begin ✍✍ (You may want to write in your journal.)

Where do problems come from? Who makes up most of the problems you must deal with? Give several examples of problems that you have posed for yourself so far today. Have you managed to solve each of these problems? Are there some problems that cannot be solved?

Which would you rather work on solving, and why?

A. A problem that a teacher or a school book gives to you?

B. A problem that you pose for yourself?

End ✍✍

A Formal Definition of *Problem*

Many people have thought about problem solving. A number of people have written books about problem solving. They have done the types of metacognition and group exercises you did earlier in this chapter. Their work has led to the following four-part definition of the term *problem*. This is the definition we will use in the rest of the book.

A problem has four parts. The four parts are listed below. As you read the four parts, compare what is written here with the Halloween costume day example given above. Each part of this definition is illustrated in Terry's example.

1. **Givens**. There is a given beginning situation. This is a description of how things are, what is happening, what is known, and so on. It is a statement of the facts of the problem situation.
2. **Goal.** There is a desired final situation. This is a description of how you want things to be. What do you want to accomplish? How can you tell if the problem has been solved?
3. **Resources and Restrictions**. What can you do that will affect the situation? What types of things can you do that might help you achieve the goal? What resources do you have? Resources include skills, knowledge, time, energy, materials, machines, money, and so on.

   What are the restrictions and rules that you must follow in working to solve the problem? Often these are not written down, but you know them. For example, YOU SHOULD NOT BREAK THE LAW. In taking a test, DO YOUR OWN WORK.
4. **Ownership—importance to you.** In order for something to be a problem for you, you must have some interest in it. You must accept some ownership. You must want to solve the problem and agree to work on it. Notice that in some cases you may be only mildly interested. In other cases you may be deeply interested.

Begin ✍✍ (Please write in your journal.)

In Chapter 2 you were asked to do a journal writing activity on IMPORTANT PROBLEMS THAT ARE EASY FOR ME. Probably you wrote very brief descriptions of the problems. Now we want you to rewrite at least two of these problems. As you do so, clearly identify the four distinct parts of each problem. An example is given below. Please follow its format.

1. Start your journal entry with a title line for the problem:

   _____

   I AM GOOD AT DOING MENTAL ADDITION PROBLEMS

2. The four parts of this type of problem are:

   Givens: I am given any two positive whole numbers that are not more three digits long.

   My Goal: To quickly find the sum.

   Resources and Restrictions: I must do it in my head. I am not allowed to use a calculator or pencil and paper.

   Ownership—importance to me: I am good at this type of problem. It makes me happy to be able to add numbers quickly and accurately in my head. It impresses my friends. I find it is useful in doing other types of math problems.

End ✍✍

A Clearly-Defined Problem

A number of people have written books about problem solving. They all agree on two things. First, to solve a problem you must have some level of interest or ownership. It takes energy and thought to solve a problem. Suppose your response to a problem situation is, "I couldn't care less." Then you will not spend time on it. Probably you will not solve the problem.

Second, experts on problem solving agree that you must understand a problem in order to solve it. What they mean is that you must have a pretty good understanding of the Givens, Goal, and Resources and Restrictions. If all of these are quite clear, we say that the problem is a **clearly-defined problem.** If they are not clear, we say that the problem is a **poorly-defined problem**. Most "real world" problem situations are not clearly-defined problems. Thus, the starting point in dealing with most real world problem situations is to first pose a clearly-defined problem.

Let's take an example. Earlier in this chapter we listed a number of problem situations that Pat encountered during the day. One of them was:

2. At breakfast, the television set is on. Pat hears the announcer talking about an African country. "The situation is grave. It is reported that 5,000 children are starving." Pat finds that it is hard to eat while thinking about these starving children.

Compare this with the four parts of a problem. Pick out the parts that are clear.

1. Givens: "The situation is grave. It is reported that 5,000 children are starving."
2. **Goal**: Notice that no goal is stated. This is often the case in real world problem situations.
3. **Resources and Restrictions**: Notice that no Resources and Restrictions are stated.
4. **Ownership—importance to Pat**. We are told that, "Pat finds that it is hard to eat while thinking about these starving children." This suggests that Pat is concerned. She would like to do something about this situation.

Suppose Pat decides she is strongly interested in doing something about the situation. Then she should work to get a more clearly-defined problem. She must pose a problem that she wants to solve.

There are many possible clearly-defined problems that can come from this problem situation. Pat needs to decide on a goal. For example, Pat might think about Goals such as the following:

2A. Goal: To provide food to some of the African children who are starving.

2B. Goal: To find out why the African country does not have enough food.

2C. Goal: To provide food for some of the people in my town who do not have enough to eat.

2D. Goal: To cut down on the waste of food that I see going on in the lunch room.

Notice how different these goals are, even though each is related to the Given situation. There are many other possible goals that might occur to Pat. Pat may think of more goals as she continues to work on this problem situation.

Even after Pat selects a goal, she still does not have a clearly-defined problem. She still needs to think about Resources and Restrictions. For example, suppose she selects the third goal:

2C. Goal: To provide food for some of the people in my town who do not have enough to eat.

Now Pat can begin to think about Resources and Restrictions that relate to the Givens and this Goal. As noted in our four-part definition of problem, often many of the Restrictions are not stated. For example, there is no need for Pat to write down that she should not steal to get money to buy food for the needy. Pat might make a list such as the following:

3. Resources and Restrictions:

A. (Resource): I am good at organizing things. I could organize a food drive.

B. (Possible Restriction): I remember that our school had a food drive last year. But there was a big argument about who the food was to be for. I think that this means that it is okay to have a food drive at our school. I could check with the school principal on this.

C. (Resource): I have a lot of friends. I think that I could get my friends to help.

D. (Resource and Restriction): I am not very busy after school. I could put in two hours each day for the next month. But I am very busy on the weekends. I don't have any free time then.

E. (Resource): I think my social studies teacher would be interested in this problem. I could probably get some help from him.

F. (Resource): My sister has a friend who has a truck. Perhaps we could use that truck.

Now Pat has posed a clearly-defined problem. She can begin to think about things that she might actually do. What is the best way to reach the goal? As Pat thinks about what she will do, she may get more ideas that fit into the category Resources and Restrictions. She might even change her mind and pick a different goal. Remember, Pat posed the problem. She is free to pose a different problem.

Begin ✍✍ (You may want to write in your journal.)

Think about one of the other goals that occurred to Pat. Suppose Pat had picked this other goal. Would the same list of Resources and Restrictions still apply? Think about some Resources and Restrictions that Pat might have for this new goal. Pretend you are Pat, and write down a list of Resources and Restrictions.

End ✍✍

Brainstorming as an Aid to Posing a Clearly-Defined Problem

At the beginning of this chapter we listed seven of Pat's problem situations. We called them problem situations because they were not clearly-defined problems. They were situations that concerned Pat. However, the Givens, Goal, and Resources and Restrictions were not clearly stated.

It often happens that a problem is not clearly defined because the Goal is not clear. Or, the Resources and Restrictions may not be clear. A good way to gain clarity is through brainstorming. Brainstorm a list of possible goals. Once a goal is selected, brainstorm a list of Resources and Restrictions. You can do brainstorming all by yourself. Or, a group of people can brainstorm together. Brainstorming is a useful strategy. It is a strategy that can be used on different parts of getting a clearly defined problem.

In brainstorming, the thing to do is to write down a lot of ideas without criticizing them. Write down whatever comes to mind. Do not spend time thinking about whether an idea is good or not so good. The task is to quickly produce a long list. Brainstorming is fun.

Begin ✍✍ (Please write in your journal.)

Consider the last item on Pat's list of problem situations.

7. Pat's social studies teacher is talking about drunk driving. The teacher says, "Last year in this country about 25,000 people died because of drunk drivers." Pat thinks about her older brother's friend who drinks and drives, and she feels scared.

1. First work all by yourself. Brainstorm possible goals that Pat might have in this problem situation. See if you can make up a half dozen different goals.
2. Now get together with two other students in your class. Compare your lists of goals. The three of you should select one goal that you would like to work on some more.
3. The three of you should do a group brainstorm on Resources and Restrictions related to the goal you have selected. You might have just one person do the writing. Or, each of you might want to write down all of the ideas in your journal. Remember, don't be critical of other's ideas!

End ✍✍

Precise Communication of Problems

Many problem situations are too big for one person to resolve all alone. You know about environmental issues such as air pollution, oil spills, and dealing with nuclear wastes. These are very big problem situations. When many people are going to work on a problem together, it is very important that the problem be clearly defined. Otherwise, the people may end up working at cross purposes with each other.

When a problem is clearly defined, it can be communicated to others. Work on solving it can be done by a number of people. They may even be located in different countries or live at different times. It may take many years for a problem to be solved.

Medical problems provide very good examples. There are medical researchers in many different countries. Suppose that a researcher in some foreign country learns how to cure a disease. Then doctors in your country can learn to use the same treatment process.

A clearly-defined problem might be broken into a number of pieces, with different people working on different pieces. A good example is provided by all of the people now working on environmental issues. They know that we live in a global village. They know that pollution from one country can affect people in another country. Each country must be involved in working on this problem.

We will come back to this idea in Chapter 10 where we talk about computer programming. A **computer program** is a set of directions telling a computer what to do. The directions must be written so that a computer can *understand* them—that is, so that a computer can do what the directions say to do.

Suppose that you are communicating with a computer. You are telling the computer what you want it to do. But you do not use precise communication. The computer cannot read your mind. It cannot know what you mean by "you know" and other expressions that people use in talking. The computer will not be able to follow your directions. Or, it may follow the directions you give, but fail to solve the problem you had in mind. Precise communication is essential in writing computer programs.

CHAPTER 3 SUMMARY

A problem has four parts: Givens, Goal, Resources and Restrictions, and Ownership. A problem is said to be clearly-defined if the Givens, Goal, and Resources and Restrictions are all quite clear.

Most problem situations are not clearly-defined problems. This is especially true of real world problem situations. It can take a lot of thinking to get a clearly-defined problem from a problem situation. Brainstorming is often a useful strategy in this thinking process.

If a problem is clearly defined, then it can be communicated to others. This allows groups of people to work together to solve the problem.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how school problems seem to be different than outside of school problems. Perhaps you thought about how it is fun to talk about school subjects to other people in the class. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.
    1. Make a title for this journal entry. Your title might look like this:

       _____

       CHAPTER 3 ACTIVITY 1

       AN IDEA I HAD WHILE I WAS READING CHAPTER 3
    2. Write down and explain the idea.
    3. Explain why the idea interests you. Why did you remember this idea?
    4. How does this idea relate to things that you do outside of this class?
    5. What else do you think about when you think about this idea?
2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Notice that this list is longer than the list from the first two chapters. This chapter contains many ideas that may be new to you. Remember, definitions are given in the Glossary.

   clearly-defined problem

   computer program

   cooperative learning

given initial situation

goal

ownership

poorly-defined problem

problem

problem posing

problem situation

resources and restrictions

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. You are talking to a close friend. Your friend says, "I'm bored. I don't know what to do this evening." Brainstorm a list of suggestions for your friend. Do this in your journal, using a title line such as:

   _____

   CHAPTER 3 ACTIVITY 5

   BRAINSTORMING ABOUT BEING BORED

6. Most likely you have been faced by the situation of a number of your teachers each giving a long homework assignment due the next day. Imagine that tomorrow that is going to happen to you. Work on this problem situation in your journal, using a title line such as:

CHAPTER 3 ACTIVITY 6

BRAINSTORMING ABOUT TOO MUCH HOMEWORK

1. Brainstorm a list of Goals that you might consider in this problem situation.
2. Then select one of the Goals from your list. Brainstorm on Resources and Restrictions that are related to this Goal.
3. Next, pick a different Goal from your list. Brainstorm Resources and Restrictions for this Goal.

7. Environmentalists are concerned about acid rain Think of this issue as a problem situation that concerns you. Develop two quite different, clearly-defined problems having to do with acid rain and you. That is, think of two different Goals. For each goal, think of a list of Resources and Restrictions.
8. Environmentalists are concerned about global warming. Think of this as a problem situation that concerns you. Develop two quite different, clearly-defined problems having to do with global warming and you.
9. Is it possible that a person has a clearly-defined problem but the problem cannot be solved? Give good arguments to support your answer. (A very good argument on one side of this question would be to give an example of a clearly-defined problem that has no solution.)
10. There are many different definitions of the word 'problem.' For example, the Merrian-Webster Pocket Dictionary, Cardinal Edition, 1951 gives the definition:

problem

1 Something to be solved.

2 Something difficult to understand.

The purpose of this activity is to compare and contrast several different dictionary definition of the word problem.

1. Make a title for this journal entry. Your title might look like this:

CHAPTER 3 ACTIVITY 10

DICTIONARY DEFINITIONS OF PROBLEM

1. Write down the definitions of problem from two or three different dictionaries.
2. Write a couple of sentences about how the definitions are alike.
3. Write a couple of sentences about how the definitions are different.
4. Give your opinion on why there are so many different definitions of problem.

11. Why do we have laws? Think about some type of laws, such as traffic laws. Explain what problem is being addressed by these laws. To do this, you might want to give two

different examples of clearly-defined traffic problems. Explain how traffic laws help solve these problems.

Chapter 4

A Four-Step Plan for Solving a Problem

ORGANIZE YOUR THINKING
How do you get started in solving a problem that you don't know how to solve? One way is to get a clear understanding of the problem. Then devise a plan of action, carry out the plan of action, and check to see if you have solved the problem. Some other key ideas in problem solving include: • Don't reinvent the wheel. Make use of previous work that you and others have done. • Each school subject focuses on how to solve the problems of its subject area.

Introduction

Chapter 3 presented the idea of a problem situation that concerns or disturbs you. It is a dissonance that prompts you to action. When you encounter a problem situation, you need to decide what to do. You may begin by posing a clearly defined problem.

But what do you do next? The problem still remains unsolved. Is there some easy way to solve every clearly defined problem?

Unfortunately, the answer is no. Some problems are very hard. There are problems that people have worked on for years. Indeed, some clearly defined problems have no solution. They are called **unsolvable problems**. For example, consider the problem of finding two positive numbers whose sum is a negative number. This is a clearly defined math problem, but it has no solution.

However, many of the problems you encounter can be solved. You can get better at solving them through study and practice. This chapter suggests two general approaches to getting better at solving problems:

1. Learn some general ways to attack problems. This chapter gives a four-step plan that is useful in attacking a wide range of problems. (Chapter 5 gives some other general-purpose methods for attacking problems.)

2. Learn to build on the work of other people. Each subject you study in school is some of the work of other people. Each subject has already been studied for many years by experts in that field. The experts have picked out some of the most important ideas. When you learn these ideas, you are building on the work of these experts.

A Four-Step Plan for Attacking a Problem

Many researchers have studied how people solve problems. They study people who are very good at solving problems. They do metacognition. They study how the human mind works as it solves problems.

Researchers have learned a great deal about how to solve problems. They have learned that there is no one method that will always work. But they have identified one general plan that is very useful. It is a way to get started on almost any problem. It has four steps and so is called the **four-step plan for solving a problem.**

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan.
4. Check to see if the problem is solved.

You should memorize this four-step plan and practice using it. Learn when it is useful to you and when it is not useful. Remember, its purpose is to help you get started on a hard problem. There is no guarantee that you will succeed in solving the problem even with this help in getting started.

A Problem-Solving Example

In this section we give an example of using the four-step plan for solving a problem. In the next section we give more detail on each of the four steps.

> Dave shares a bedroom with his younger brother Tom. Their mother is angry because the room is so messy. She says, "Dave, you are five years older than Tom. You are old enough to take responsibility for your room. I want you to see that the room is kept neat and clean. I think that Tom should help." Dave feels a little guilty about how messy the room is. He realizes that he has been setting a bad example for his younger brother.

Dave has a problem situation. He decides to use the four-step plan to attack this problem situation.

1. Understand the problem. (This first step uses the ideas of Chapter 3.)

1. Givens: Dave and Tom are brothers who share a bedroom. Dave is five years older than Tom. Their room is messy. Mother is angry.
2. Goal: Keep the room neat and clean.
3. Resources and Restrictions: These are not clearly specified. A few ideas occur to Dave.

A. I have good organizational skills. I could organize the job so it is easier to do. I could break the job into some parts to be done each day and some parts to be done each week.

B. I am a fast worker. I could do all the work myself. But that doesn't really seem fair. I think Tom should help, and so does mother.

C. I have a habit of throwing my dirty clothes on the floor. Tom and I have a clothes hamper. But right now my model airplane is sitting on it.

D. My younger brother really likes and trusts me. He likes to do things with me. I bet I could get him to help if we worked together.

E. I am good at building things, and so is my dad. We could build some more shelves. That might help.

4. Ownership–importance to Dave: Dave has respect for his mother and is concerned that she is angry. He realizes that he has been setting a bad example for his brother. Thus, he has a reasonable level of interest in resolving the problem situation.

2. Devise a plan of action.

Dave thinks about the situation. Various plans come to mind. He thinks about getting more shelves. But he realizes that he already has plenty of storage space.

Finally Dave decides, "I think the best approach is to divide up the task and to make a wall chart. I'll list all of the jobs that need to be done. Tom and I will take turns picking the ones that we will do. Because Tom is younger than me, I'll let him have the first choice."

3. Carry out the plan.

Dave approaches his younger brother and explains the situation. He and Tom make a list of the jobs that need to be done each day. They make a list of the jobs that only need to be done once a week. They make a wall chart for checking off the jobs. They agree who is to do each of the jobs. They agree that they will work together on Saturday morning to get ready for mother's inspection.

4. Check to see if the problem is solved or new problems have been created.

A week goes by. Every day Dave and Tom each do some work on the room. On Saturday morning they work together to get the room ready for mother's inspection.

The room is neater and cleaner. Dave and Tom's mother is happy with the progress. But she sees some other things that need to be done. She suggests that the wall chart needs several additions. Good progress has occurred. The problem is nearly solved!

Or, is it solved? What can go wrong? Suppose that Tom stops doing his share of the work, or does a poor job? After all, Tom is quite young. Maybe it isn't fair that Tom has to do half of the work.

Suppose that Dave wants to be out with his friends on Saturday morning when a lot of the work is usually done? Discuss some of these questions in your journal.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   THE PROBLEM OF A MESSY ROOM

2. Discuss possible answers to the question of what might go wrong. Then suggest ways to handle these situations.
3. Think of an entirely different plan of action that Dave might try. For example, Dave might agree to do all of the work one week, and Tom would do all of the work the next week.
4. Get together with a classmate and share your ideas on a new plan of action that Dave might take.

End ✍✍

More Details on the Four-Step Plan

The four-step plan is quite general. It may help you to get started in working to solve personal problems and school problems.

Please remember, the plan is just a way to get started. You don't have to follow it if it doesn't seem to be helping. Also, it is okay to skip around in using the plan. For example, suppose you think you understand your problem and you begin to develop a plan of action. But in thinking about the plan, you realize that you don't really understand the problem. Then the thing to do is to go back the first step again.

Or, you develop a plan of action and you start to carry out your plan. You realize that that isn't doing any good. Your plan of action will not solve the problem. Maybe you need to rethink your problem. In that case, you start over again at step 1. Perhaps you need to develop a different plan. Then you will need to go back to step 2.

Here are some more ideas about the four-step plan for attacking a problem.

1. **Understand the Problem:** This is a feeling and thinking step. Ownership is very personal. Often you begin with a problem situation. You work on the problem situation to pose one or more clearly-defined problems. You can do this using ideas from Chapter 3. You want to pose one clearly-defined problem that you will attempt to solve.
2. **Devise a plan of action**: This is a thinking step. In getting a clearly-defined problem, you identified Resources and Restrictions. Now you begin to think about how to use the Resources and how to avoid violating the Restrictions. You mentally develop a plan of action of what you will do to solve the problem. Perhaps you write down your plan of action.

3. **Carry out the plan of action**: This is an action step. Notice the clear distinction between thinking about the plan of action (deciding what to do) and actually carrying out the plan of action. In Step 2 you can imagine carrying out the plan. Perhaps you can see yourself carrying it out in your mind's eye. In Step 3 you actually carry out the plan of action.

   This distinction is quite important. Computers are very good at carrying out some plans of action. (Remember, a computer program is a detailed step by step plan of action. It is designed to be carried out by a computer.) It is people who devise the plans of action that computers carry out.

4. **Examine and think about the results of your work**. This is a thinking and a values step, drawing on everything you know. It has two parts:

   A. **Check to see if the problem is solved**. Has the Goal been achieved? If yes, then you are done. But suppose not. This can happen if your plan is flawed. (Then you will need to return to Step 2.) It can also happen if you make a mistake in carrying out your plan. (Then you will need to return to Step 3.)

   B. **Check to see if new problems have been created**. The steps you take to solve one problem may create other problems. For example, suppose that you have saved up some money to buy some clothes that you really need. But you are bored. You decide to take a friend to a movie. You have solved your boredom problem. But now you have the problem of not having money to buy the clothes you need.

Begin ✍✍ (You may want to write in your journal.)

People often seem to forget that the process of solving a problem may create a new problem. Think of several examples where the steps you took to solve a problem created new problems.

End ✍✍

Don't Reinvent the Wheel

The four-step plan can help you get started on many different kinds of problems. But all by itself, it often does not help much.

For example, suppose that the math teacher gives you a hard problem from a class that you plan to take next year. The problem uses words and symbols that you have never seen before. You cannot even begin to understand the problem. You have no idea of the Givens or the Goal. You lack the Resources (the knowledge of math) that are needed to solve the problem.

This same situation exists in every other school subject. People have been working for hundreds of years to learn to solve problems in art, music, science, and social studies. They have made a great deal of progress. Some researchers spend years and years working on the details of a single problem. Suppose that you encounter one of these really hard problems? What should you do?

Begin ✍✍ (You may want to write in your journal.)

You have heard the expression, "Don't reinvent the wheel." What do you think that this has to do with problem solving? What does it have to do with solving really hard problems that other people have already solved?

End ✍✍

Build on the Previous Work of Yourself and Others

Suppose that you encounter a problem that you have solved before. You were happy with the results. Then probably the way to solve it is to just do the same thing again. It is helpful to have a good memory. You learn from your successes and your failures.

Now think about the successes and failures of other people. Thomas Edison worked for years to develop a good light bulb. He had many many failures. But eventually he succeeded. Most people don't care about all of his failures. Instead, they use light bulbs built using the ideas of his success.

This is a key idea. Suppose that you encounter a problem that someone else has solved before. If someone has already figured out how to solve a problem, then why not just use that person's method? Learn to build on the work of others.

Here is a summary of the ideas in this section. These are some of the most important ideas in this book.

1. When you encounter a problem situation, think about whether you have encountered it before. If it is a situation you have encountered before, what did you do previously? Did it work well for you? If so, most likely you will want to do the same thing again. If it didn't work well for you, most likely you will want to try something different. You may want to set a different goal. You may want to try a different plan of action.
2. Suppose you encounter a problem situation that is new to you. First work to get a clearly-defined problem from it. Then find out what other people have done when they were faced by that clearly-defined problem. You might find out by talking to other people. Or, you might find out by looking it up in a book.

This suggests two very good ways to get better at solving problems. First, solve lots of different problems and remember how you solved the problems. Remember your successes and your failures. Experience is an excellent teacher. You get better with practice.

Second, learn to build on the work of other people. There are many ways to build on the work of other people. For example:

- Learn to talk to people, to get their help in solving problems. Learn to work with groups of people.
- Learn to make us of reference books. A library is full of information about how to solve specific problems.

- Learn the subjects taught in school. Each school subject is designed to help you learn things that other people have already learned. Each school subject helps you to learn to solve certain types of problems.

Begin ✍✍ (You may want to write in your journal.)

There are many ways to build on the work of other people. Several of them are listed above. Add to the list. Then decide which ways are best for you. For example, are you better at talking to other people or using a library?

End ✍✍

The Basics of Education

School helps you learn to build on the work of other people. You have heard about "the three Rs." Reading, 'riting, and 'rithmetic are some of the basics of education. They are called basics because they are useful in so many different ways. They are especially useful when you want to build on the work of other people.

Reading provides a good example. Because you know how to read, you can look up information in a library. You can read about the work that other people have done. You can make use of this as you work to solve your own problems.

There are a number of "basics" of education. Each is important in understanding and solving a wide range of problems. However, perhaps some of the basics of education are more important to you than others. Think about that as you do the following journal writing activity.

Begin ✍✍ (Please write in your journal.)

A whole lot of school is devoted to helping you get better at some of the basics, such as reading, writing, arithmetic, speaking, and listening. Please do the following journal writing activity.

1. Make a title for this journal entry. Your title might look like this:

_____

USING THE BASICS OF EDUCATION TO SOLVE PROBLEMS

2. Give a clearly-defined problem that you have solved in which you made use of your ability to read.
3. Give a clearly-defined problem that you have solved in which you made use of your ability to write.
4. Give a clearly-defined problem that you have solved in which you made use of your ability to do arithmetic.
5. Give a clearly-defined problem that you have solved in which you made use of your ability to speak.
6. Give a clearly-defined problem that you have solved in which you made use of your ability to listen.

End ✍✍

School Subjects

Each school subject focuses on one area. A science class focuses on what people know about science. It helps you to understand the types of problems that scientists know how to solve. It helps you to understand the types of problems that scientists are currently working on. One major goal in a science class is to help you learn to think like a scientist. Learn to attack problems the way a scientist does.

Scientists use the "scientific method." They develop theories that describe what is happening. Then they work to test their theories. For example, Albert Einstein developed a theory about moving objects. His theory helped explain what happens when an object moves very fast. He and a number of other scientists worked to design tests of his theory. Einstein's theory is quite famous. It is called the theory of relativity.

The types of problems one studies in each subject are different. But often there is an overlap between courses. The types of problems that one learns about in a health class are different than the types of problems one learns about in a history class. But in a health class you might learn some of the history of medicine. In a history class you might learn some of the health problems that people had a long time ago. In both classes you might use ideas from math to draw a bar graph. The methods used to solve problems in one subject may be the same as the methods used in another subject.

It is very helpful to know a little bit about every school subject. This will help you to understand the kinds of problems the subject deals with. Even just a little bit little bit of knowledge can be the starting point for solving a problem that deals with a subject area.

CHAPTER 4 SUMMARY

Many problems can be solved by following a four-step plan:

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan of action.
4. Check the results.

In devising a plan of action, it is very helpful to build on the things that you already know and the things that other people know. School helps you to learn the things that others have already discovered about solving problems. Each school subject focuses on understanding and solving problems in one particular field.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how you build on your experiences. Perhaps you thought about why some school subjects are more fun for you than other school subjects. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    _____

    CHAPTER 4 ACTIVITY 1

    AN IDEA I HAD WHILE I WAS READING CHAPTER 4

    2. Write down and explain the idea.
    3. Explain why the idea interests you. Why did you remember this idea?
    4. How does this idea relate to things that you do outside of this class?
    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

    In talking about your topic, try to make use of some of the new terms introduced in this chapter as well as terms from the earlier parts of the book. A list of new terms is given below. Remember, definitions are given in the Glossary.

    four-step plan for solving a problem

    unsolvable problem

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Each class you take focuses on a particular type of problem. The main goal of a math class is to help you understand and learn to solve math problems. The more you know about math, the better you will be at solving math problems. Please do the following journal writing activity. You may want to get some help from a math teacher. Use a title line such as:

   _____

   CHAPTER 4 ACTIVITY 5

   SOLVING PROBLEMS USING MATH

   1. What is math? Write a brief definition that you feel adequately defines the field. Your definition should be understandable by other students in your class.
   2. What are some of the types of problems that people learn to solve by studying math?
   3. Give some examples of problems in non-math subjects that math can help solve. To do this, think of each subject that you are taking. For each one, give an example of where math can be used.
   4. Give two different examples of problems that occur outside of school where math is useful.

6. Do the above exercise for some other subject area that you are studying.
7. Many years ago people were faced by a transportation problem. They invented the automobile to help solve this problem. Give several examples of problems that this "solution" has created.
8. Brainstorm on the following questions:
   A. What problems does television help solve?
   B. What problems does television help create?
9. Brainstorm on the following questions:
   A. What problems does school help solve?
   B. What problems does school help create?

10. One way to tell if you have solve a problem correctly is to ask the teacher. Brainstorm a list of other ways to tell if you have solved a problem correctly. Then get together with two other students in the class and share your lists. Do some more brainstorming in your group. It is very important to understand that once you get out of school there will not be an "answer book" or a teacher to tell you if your answers are correct.

Chapter 5

Problem-Solving Strategies

ORGANIZE YOUR THINKING
A strategy is a general plan of action for attacking a problem. Some strategies are only useful in a specific subject area or type of problem. A strategy for solving science problems might not be useful in solving sports problems. Other strategies are useful for a wide range of problems. You can get better at problem solving: • By learning to use strategies designed to fit problems in one subject, such as math strategies and business strategies. • By learning to use a number of strategies designed to be useful in many different problem areas. • By learning roles of computers in making use of strategies.

Introduction

Chapter 4 contains a four-step plan that can be used to attack a wide range of problems. It does not solve any specific problem for you. But quite often it will tell you how to get started. That is very important. If you can get started on a problem, then you have a chance to solve the problem.

The four-step plan is an example of a problem-solving strategy. A strategy is a plan of action. It tells you some things to do or think about that might help solve a problem. By learning to use the four-step strategy, you can get better at solving problems.

There are many strategies for problem solving. Some are useful for a wide range of problems. For example, consider a strategy for dealing with people. A useful strategy is, "Be a good listener. Be interested in what others have to say." This strategy is useful in dealing with all people that you meet.

Other strategies are quite specific and are useful for just a narrow range of problems. For example, here is a strategy that many students use in a math class. "When you have to do a problem from the book, page back into the chapter until you find a worked out example. Do the same thing that was done in that example." Often this strategy will help you solve the book problem.

However, this is not a very good strategy. First of all, lots of times it will not help you solve the book problem. But more important, it is a poor strategy for learning math. The purpose of math homework is to help you learn math—not just "get the answers." It is necessary to understand the problem and to think carefully about what you are doing, if you are going to learn math.

Strategies for Getting Better at Solving Problems

Your mind is good at learning strategies. When you solve a problem, your mind remembers the general ideas of what you are doing. Suppose that some time later you encounter a somewhat similar problem. Your mind may recognize the new problem as somewhat similar to one you have solved before. It will suggest that you use the same approach that you used before. That is, your mind tends to use the strategy, "Do what worked before."

However, there are lots of different strategies. Sometimes your mind will develop a strategy that doesn't work very well. You will use the strategy over and over again, even though it isn't very useful. Can you think of an example?

This is a key idea. Your mind may be very happy trying the same thing over and over again, even when it doesn't seem to be working. It gets "stuck in a rut." It requires careful thinking to get out of such a rut. When you are working on a problem and your strategy isn't successful, don't just keep doing the same thing over and over again. Do something different! Almost anything different is better than continuing in the rut that doesn't work.

Begin ✍✍ (You may want to write in your journal.)

Think of at least two different strategies that you often use, but which often don't work very well. For example, you may have a certain strategy you use in dealing with a younger brother or sister. You may have a certain strategy you use in dealing with your parents. You may have a certain strategy you use in studying for major tests.

End ✍✍

In this chapter you will learn more about strategies. You will learn some very powerful strategies that may help you to solve hard problems.

Begin ✍✍ (You may want to write in your journal.)

Suppose that your teacher is going to give a big test next week. Think of three different strategies you might use so you will do well on the test. For example, perhaps you use the strategy of "cramming" the night before the test. Which strategy seems best to you? Is this strategy best for all subjects you are taking?

End ✍✍

There are Lots of Strategies

Researchers have found that most students know just a few general strategies for attacking problems. They use the same strategies over and over again. Sometimes

the strategies work. But other times they don't work. Then the student is stuck, with no idea of what to do.

You can get a lot better at problem solving by learning additional general strategies. It is easy to memorize some new strategies. But it is much harder to learn when and how to use the strategies.

For example, suppose you are working with a problem situation where there is no clear goal. Here are some strategies for getting a list of possible goals:

1. Brainstorm all by yourself.
2. Brainstorm in a group or with a friend.
3. Ask your teacher for some possible goals.
4. Read a book on the topic. Find goals suggested by the author.
5. Examine your feelings very carefully. Why do you have some Ownership in this problem situation? What would make you feel better about the situation? Think of goals that will make you feel better.

Each of these is a general strategy. Each may be very useful for some situations and not useful for other situations. For example, if you are taking a test, you can use the first strategy. Unless it is an open book test, you are not allowed to use the fourth strategy.

When you are solving a problem, one of the resources is your time. Usually you will be able to think of several different strategies to use on a problem. But you may not have enough time to apply every possible strategy that you can think of. You want to apply a good strategy–one that will work well. How can you tell which strategy to try first?

There is no easy answer to this. However, training and experience can help. To a large extent, you have to teach yourself. The way to do this is by metacognition. As you solve problems, think about what you are doing. Think about the strategies you are using. Think about other strategies that you have decided not to use. This type of metacognition will help you to become much better at solving problems.

Begin ✍✍ (Please write in your journal.)

In this activity you will need to work alone for a while. Then you will want to share your results with a group of students in your class.

You spend a lot of time in school memorizing facts. You memorize how to spell words. You memorize important names and dates. You memorize formulas in math and science.

1. Make a title for this journal entry. Your title might look like this:

_____

STRATIGIES I USE TO HELP ME MEMORIZE THINGS

2. Make a numbered list of at least three different strategies that you use to help you memorize things.
3. Discuss which one or two are best for you, and why.

Now get together with two or three other students. Share your strategies. Talk about what works best for each of you. When you learn some good ideas, write about them in your journal. Have any of the people in your group read a book on how to get better at memorizing?

End ✍✍

The Top-Down Strategy

There are many general-purpose strategies that may help you solve a problem. For example, consider the following strategy that was mentioned in Chapter 1.

> Break big problems into smaller problems. (The smaller problems may be much easier to solve.)

This is such an important strategy that it has a name. It is called the **top-down strategy**. The idea is to start at the "top" of a problem—with the big picture. Break the problem "down" into smaller pieces.

The top-down strategy is so useful and so easy to use that you do it all of the time. Probably you don't even think about it. For example, you wake up in the morning and it is a school day. You have the problem of getting to school. You break it into smaller problems:

1. Getting dressed, combing hair, brushing teeth, and so on.
2. Getting breakfast.
3. Getting the stuff ready that you need to take to school.
4. Getting to the bus stop in time to catch the school bus.

For another example, suppose that a teacher assigns a big term paper. You might break this task into some smaller tasks.

1. Decide on a topic.
2. Find a number of sources of information about the topic.
3. Read the information and keep good notes.
4. Write the paper.

Begin ✍✍ (You may want to write in your journal.)

Sometimes when you break a big problem into smaller problems it is clear that the smaller problems must be solved in a certain order. In other cases the order does

not make any difference. It may be best to work on one of the sub problems for awhile, and then switch to another. Think about the examples of getting to school and doing a term paper given above. Does it make any difference in what order you do the smaller problems?

Make up an example in which the order of doing the sub problems is very important. For example, suppose you are planting some flowers in a garden. You are going to dig a hole, put a plant in, and fill the dirt in. What happens if you do these steps in a different order?

End ✍✍

The Bottom-up Strategy

There is another general-purpose strategy that you also use quite often. Probably you have watched a small child play with building blocks. There does not seem to be any plan in what the child is doing. The child puts several of the blocks together. The child is pleased with the result and adds more blocks.

The **bottom-up strategy** begins with "building block" problems. These are problems that you know how to solve and tasks that you know how to do. You put some of them together. As you see what results, perhaps you are led to add more parts. Perhaps you are led to setting a goal. This is a very creative process. Many artists work this way.

The bottom-up strategy is used in two different ways. Sometimes it is used with no goal in mind. The initial activity may seem rather random, like a child playing with building blocks. A goal is created that fits with the progress that has occurred. For example, you begin to doodle. You draw several different shapes. Then you see that one of the shapes looks like the tail of a cat. Another of the shapes looks like a tree branch. You decide to draw a picture of a cat in a tree.

At other times the bottom-up strategy is goal directed. For example, it is after school and you are hungry. Your goal is to get something to eat. You go to the kitchen to get a snack. You open the refrigerator and see some sandwich makings. You look in the bread drawer and see a loaf of bread. You decide that you would like a sandwich. You have used a bottom-up strategy to decide on the goal of making a sandwich.

Begin ✍✍ (You may want to write in your journal.)

Think of two different times that you have used the bottom-up strategy. First think of a time that you were goal-directed. Then think of a time you used the bottom-up strategy and were not goal directed.

Which of the two examples seemed easiest for you to think of? Why?

End ✍✍

Primitives: Building Block Problems

In using the top-down strategy, the goal is to reach smaller problems that you know how to solve. In using the bottom-up strategy, the starting point is smaller problems that you know how to solve.

In both cases, you need to have a set of building blocks—problems that you know how to solve, or tasks that you know how to do. These are called **primitives**. A primitive is a problem that you know that you can solve. Usually it is a problem that you can solve quickly and easily. It is a resource that is available to you when you begin to attack a problem.

For example, do you know the "times" table? Can you quickly and easily give the answer to simple problems such as 8 x 9, 3 x 7, and 6 x 8? If so, then you have a set of primitives that are very useful in many different situations. These multiplication fact primitives are useful in doing larger multiplication problems. They are useful in doing paper and pencil long division. They are useful in doing mental estimations on arithmetic problems.

This book uses the word **primitive** for a basic building block problem or task. Sometimes other words are used in different fields. In sports, for example, it is necessary to learn the basic moves or the fundamentals. The basic moves and the fundamentals are primitives.

Begin ✍✍ (You may want to write in your journal.)

Think of some field that you know well. Maybe you are good at ballet. Maybe you are good at woodworking. Make a list of primitives for the field that you select. Remember, these are building block problems that you can easily solve.

End ✍✍

A Calculator Primitive

One way to get better at problem solving is to learn more primitives. That is what you do when you take a course in school. A course teaches you some of the primitives that are useful in solving the problems in the course.

But it takes a lot of time and effort to learn new primitives. People are always searching for ways to avoid this work. One way is to build a machine that can solve certain kinds of problems. A hand held calculator is a good example of such a machine. Even an inexpensive calculator can add, subtract, multiply, and divide. That is, it can carry out the process needed to solve four different types of problems. It provides you with four different **calculator primitives**.

A hand held calculator is a limited purpose computer. It contains the same type of circuitry, although usually there is not as much of the circuitry. There is no clear dividing line between a calculator and a computer. An expensive calculator has many computer-like features. Some of the least expensive computers are not as powerful as some of the more expensive calculators.

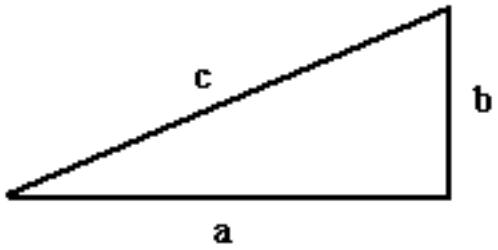
Most hand held calculators have a key that is labeled √. This is the square root key. Suppose that you enter the number 144 into the calculator and then push the √ key. The calculator will find the square root of 144 for you. It will quickly display the number 12. The square root of 144 is 12, because 12 x 12 = 144.

(Note: This is not a math book. Students of mathematics know that a positive number has two square roots. Both +12 and -12 are square roots of 144. But we will just talk about "the" square root of a number. We will mean the positive square root.)

The problem of finding the square root of a number occurs quite often in engineering, science, and math. It is a very important primitive. There are two aspects of this primitive. First, what does "square root" mean? That is, what is the concept of square root? Second, how do you calculate the square root of a number? What process does one do to find a square root?

It is easy and fun to learn the concept of square root. You can easily see that 4 x 4 = 16, so that 4 is the square root of 16. You can easily see that 1.3 x 1.3 = 1.69 so that 1.3 is the square root of 1.69. Note that 1/2 x 1/2 = 1/4. In this case, the square root of a number is actually bigger than that number!

In addition, you can experience the joy of the Pythagorean theorem. It is an important application of square root. Take a look at the right triangle given below.



The sides of the triangle have lengths a, b, and c. The angle between the sides of length a and length b is 90 degrees. The Pythagorean theorem tells how to find the value of c when you know the values of a and b. The way to do it is to calculate the value of $a^2 + b^2$. Then calculate the square root of this number. For example, suppose that a = 4 and b = 3. Then c is the square root of 25.

The Pythagorean theorem illustrates a very important idea in problem solving. It is the idea of building on the work of others. The theorem was first discovered and proved more than 2,000 years ago. Since that time, many millions of people have built on this important piece of work done by Pythagoras.

As you can see, the concept of square root is not too hard to learn. It is much harder to learn to calculate the square root of a number. It used to be that schools taught students to calculate square roots by hand. Students were required to memorize how to do this. The procedure they learned is much more complicated than long division. Most students take a long time to memorize this procedure. They soon forget it unless they use it regularly.

Now most schools have dropped this topic from their high school math classes. Students are taught the concept of square root. They are taught how to use a calculator to find the square root of a number. Thus, students have square root as a calculator primitive in solving engineering, science, and math problems. They still learn the concept of square root. But they save a lot of time. It is much easier to learn to use a calculator than it is to learn to calculate square root by hand.

Begin ✍✍ (You may want to write in your journal.)

The square root example has two parts. It has the concept of the square root problem. It has the process of how one actually solves a square root problem. All problems have these two parts.

Think of some problems that you know how to solve. For each, separate the concept from the process. To do this, describe the concept without describing the process. For example, think about looking up a word in a dictionary or looking up a topic in the library. In each case the concept and the process are two different things.

End ✍✍

Computer Primitives

A computer program is a detailed step by step set of directions. It is a plan, telling a computer what to do. A computer program may be a plan telling a computer how to solve a particular type of problem. It may be a plan telling a computer how to accomplish a particular task.

Suppose that you have access to a computer and a large collection of computer programs. You can think of each of these computer programs as a **computer primitive**. Each computer program can quickly and easily solve a problem or do a task for you. The computer gives you a very large number of primitives.

But remember, a primitive has both a concept and a process. The computer can quickly and accurately carry out the process. But this is of no use to you unless you understand the concept.

This may be the single most important idea about computers. A computer can help you to gain a very large number of primitives. There are many thousands of computer programs that solve problems. Each problem has underlying concepts. A computer can carry out the process of solving these problems. If you learn the concepts for these problems, you will have gained the problems as primitives.

Begin ✍✍ (You may want to write in your journal.)

You have seen posters and drawings done by a graphic artist. The lettering in these products is done very precisely and neatly. A graphic artist is skilled in doing the designs for the posters and drawings. A graphic artist may also be skilled in actually doing the lettering and drawing by hand. But often a computer can do the

lettering. It is easy to learn to use a computer to do neat and very precise lettering. It is much harder to learn the concepts of designing a poster or drawing.

Give several examples of processes that you know a computer can do. Give the concepts that a person would need to learn in order to make good use of these computer processes.

End ✍✍

CHAPTER 5 SUMMARY

Strategies are plans of action. They are general ways to attempt to attack a problem. Some strategies are very specialized. Other strategies can be used on a wide variety of problems.

1. The top-down and the bottom-up strategies are very useful for many different problems.

2. Primitives are problems that you can solve easily and accurately. You use them in the top-down strategy and in the bottom-up strategy.

3. A primitive consists of both a concept of a problem and a process for doing the problem.

4. A computer can carry out the process needed to solve many problems. If you learn the concepts of these problems, you will have gained them as primitives.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about some problem-solving strategies that you use all of the time. Perhaps you thought about some strategies that are not mentioned in this chapter. Perhaps you thought about the fact that school spends a lot of time teaching you to do things that computers can do. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 5 ACTIVITY 1

   AN IDEA I HAD WHILE I WAS READING CHAPTER 5

   2. Write down and explain the idea.
   3. Explain why the idea interests you. Why did you remember this idea?
   4. How does this idea relate to things that you do outside of this class?
   5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter as well as terms from the earlier parts of the book. A list of new terms is given below. Remember, definitions are given in the Glossary.

   bottom-up strategy

   calculator primitive

   computer primitive

   primitive

   top-down strategy.

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Think of a strategy that you use when you have a problem with a friend. Likely you have used this strategy in dealing with other people. Give an example of how this strategy can be used with people who are not your friends.

6. Pick one of the courses that you are taking. Make a list of some of the primitives that you are learning in that course.

Now pick a different course that you are taking. Make a list of some of the primitives that you are learning in that course.

Which course seems to have the most primitives? Why do you think one course contains more primitives than the other?

7. For this activity, use the same courses that you used in Activity 6 Look at the two lists of primitives. For each primitive, think about a process for solving the primitive. Which of these processes do you think a computer could do?

   Does one of the courses seem to have more computer primitives than the other? Why do you think this is the case?

8. A primitive consists of both concepts and processes. Some people are better at learning concepts. Other people are better at learning processes. Which are you better at?

   In answering this question, think about the examples from Activity 6.

9. There are many different ways to solve most problems. For some primitives, you will want to know how to do the process by hand and by computer. The problem of checking your spelling is a good example. Sometimes you need to check by hand. Other times a computer is very helpful.

   Give other examples of where it is very useful to know both a by hand and a by computer method for solving a primitive.

10. Make a list of strategies that you use to cope with:

    A. The course you do best in.

    B. The course you do worst in.

    Compare and contrast the strategies. Draw conclusions if possible.

Chapter 6

Getting Better At Thinking

ORGANIZE YOUR THINKING
This chapter discusses a number of things that you can do to get better at thinking. As you get better at thinking, you will get better at solving problems. To get better at thinking: • Learn what more effective thinkers do. • Understand your own more effective thinking skill habits and your less effective thinking skill habits. • Develop more effective thinking skill habits and practice them.

Introduction

Chapter 1 talks about two goals of education. These goals are to help students:

1. Learn important information and gain important skills.
2. Get better at thinking and problem solving using the information and skills they have learned.

Both help in problem solving. Consider the first of these. Suppose that you have only a small number of kinds of problems that you need to solve. The same problems keep coming up over and over again. Then the thing to do is to learn how to solve these specific problems. Learn the information and skills needed to solve these problems. Practice solving the problems until you can solve them rapidly and accurately. This is very efficient. When one of the problems comes up, you solve it by doing what you have done before. You build on your own previous work.

As an example, consider the problem of keeping your shoes on and your shoe laces from dangling. When you were quite young, you learned how to tie a shoe. You practiced this task over and over again. You have learned how to tie your shoes without even thinking about it. You have learned the process so well that you can do it without conscious thought.

Or, consider a good athlete. The athlete must know the rules of the game. During an important play, the athlete does not have time to stop and think about the rules. Also, the athlete has practiced fundamental skills needed in the game over and

over again. The athlete performs these skills automatically, without conscious thought.

As another example, consider the problems of counting money and making change. These are problems that you probably deal with every day. It is very important that you learn how to solve these problems accurately and rapidly. School can help in this learning task. However, many people with little schooling have also learned to solve these problems. They get very good at solving these problems through lots of practice.

The key point is that your mind is very good at learning to solve the problems that it frequently encounters. But it takes quite a lot of time and effort to learn all of the details on how to solve a type of problem. It takes a lot of practice to get good at solving the problem without making any mistakes. There are so many different problems that you might encounter that there is not enough time to learn how to solve each one.

We have now arrived at one of the most important questions in education. How should school time be spent? For example, how should it be divided among:

1. Learning basic information and skills. (Gaining primitives.)
2. Learning to solve specific problems that occur frequently and that are considered to be quite important.
3. Developing general-purpose problem-solving and thinking skills that can be used with any problem that you encounter.

Begin ✍✍ (You may want to write in your journal.)

Think about the three ways of spending school time that are listed above. One approach would be to spend about one-third of the time in each category. What do you think about that? If you were in charge of schools, how would you divide up the time? Do you think that the division should be the same for every student?

End ✍✍

It seems clear that schools should spend quite a bit of time helping students gain general-purpose problem-solving skills. The task is to help prepare students to deal with the unexpected. Help them learn to solve problems that they have not seen before.

One way to do this is to help students become more effective thinkers. You have a very good mind. With training and experience, you can get more and more effective at using your mind. This chapter will give you some help in becoming a more effective thinker.

What is Thinking?

The word *think* has a number of meanings. Each person has good ideas on what the word means for them. Please do the following journal writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

_____

WHAT DOES THE WORD *THINK* MEAN?

2. First work by yourself. Brainstorm a large number of ideas of what *think* and *thinking* mean to you.
3. Get together with two other students in your class and share your ideas.
4. Then write a good definition of *think* in your journal.

End ✍✍

Now think about the definition that you wrote in your journal. Does your definition indicate that people can get better at thinking? Does your definition suggest that different people think in different ways?

Do some metacognition. When you think, do you make pictures in your head? When you think, do you talk to yourself inside your head? When you think, do you have hunches or use your intuition? When you think, do you sense your feelings?

Begin ✍✍ (You may want to write in your journal.)

There are many ways to think. Some people are better at thinking in pictures. Others are better at thinking in words. Both are very useful. Which are you better at? How do you know this?

Try the following experiment. Your goal is to think of two different problems that you have solved today. The first problem should be one where you used pictures in your head as an aid to thinking. The second should be a problem where you used words in your head as an aid to thinking.

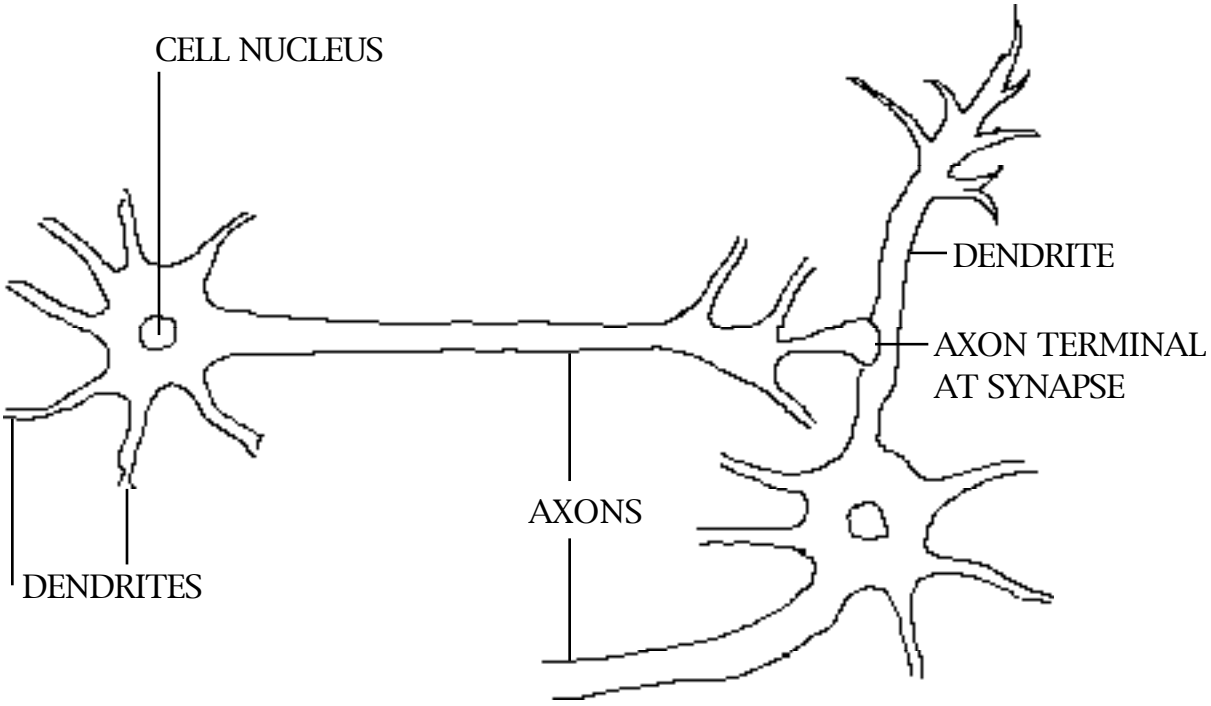
Now, do some metacognition on the task you just completed. Did you use pictures in your head or words in your head as you carried out the experiment?

End ✍✍

Brain Theory

The human brain is very complex. Brain researchers have been making a lot of progress in recent years. But the brain is so complex that they still have a lot to learn. Researchers are just beginning to understand how the brain learns and what helps it to learn. They are just beginning to understand what the brain does when it is thinking. They are just beginning to understand what happens to the brain when it gets a disease such as Alzheimer's.

One of the basic building blocks in the brain is the neuron. The neurons store and process information. A typical human brain has between 30 billion and 100 billion neurons. A neuron is so small that 30,000 of them will fit into a space the size of a pinhead! The neurons store information and they also process information. The picture given below shows two neurons.



In recent years, scientists have developed ways to "see" the brain in action. They can actually take pictures that show which parts of the brain are active when it is doing various tasks. Several key ideas have emerged:

1. Most brain activity occurs at a subconscious level. When we talk and think about a problem, billions of neurons may be involved. We do not consciously control all of this neuron activity.
2. Good thinkers make more efficient use of their brains than do poor thinkers. That is, when a good thinker is solving a problem there is less brain activity than when a poor thinker is working on the same problem. Training and practice make the brain more efficient. There is a good analogy with the economy of motion of a trained athlete. The trained athlete has economy of motion. Energy is not wasted!

You have seen many highly trained athletes. They have learned to make very effective use of their minds and bodies in dealing with athletic tasks. They get better through hard work, continued practice, and continued study.

The same ideas hold for becoming a more efficient thinker. You have a very good brain. Through study and practice your mind will become more capable. You can become a more efficient thinker.

Persistence in Problem Solving

Educators have done a lot of research on thinking and problem solving. They have studied how people think and solve problems. They have carefully studied people who are efficient thinkers and people who are less efficient thinkers. They have developed a number of ways to help students get better at thinking and solving problems.

You know that many problem situations are very complex. They do not have easy solutions. It is easy to make mistakes when dealing with hard problems. Solving hard problems can take a lot of time and effort. Some people are much more persistent than others.

Researchers have found out that the more effective thinker is willing to work long and hard on a problem. Thomas Edison was a very hard worker. He once indicated that his success as an inventor was based on "98% perspiration and 2% inspiration." A good example is provided by his work in inventing the electric light bulb. The problem was to develop a filament that would give good light and not burn out very fast. Edison tried hundreds of different materials. It was only through great persistence that he finally came up with a good, useful, light bulb.

Researchers have found out that people who are poor at solving problems often lack persistence. When they have a problem, they try one or two different things. If they don't quickly succeed, they give up.

Of course, blind and unthinking persistence is not useful. If one approach is not working, try a different approach! Don't just keep doing the same thing over and over again if it is not working. Learn to recognize when the approach you are using isn't working.

Begin ✍✍ (You may want to write in your journal.)

Think about your persistence in solving problems. Do you give up easily, or do you keep trying? How would you compare your persistence with that of your friends?

Give an example where you kept trying, and eventually solved a hard problem. Give an example where (maybe) you gave up too soon.

Probably you are more persistent on some problems than on others. Can you tell in advance of starting a problem how persistent you will be? What kinds of problems are you apt to be most persistent on?

End ✍✍

The type of metacognition in the journal writing activity is very important. You can look at your own habits. Whey you have a problem, do you keep working until you solve it? Or, do you give up easily? Persistence is very important. You will get better at problem solving if you learn to "keep trying."

In the rest of this chapter we will discuss a number of other "more efficient" thinking and problem-solving habits. You may find that you have many quite efficient thinking skill habits. But you may also find that some of your thinking skill habits are not as efficient as they could be. This is very valuable information. It can provide a starting point for improving your ability to think and solve problems.

It is not easy to change your thinking skill habits. After all, you have been practicing some of these habits for years. They have served you quite well. But you can get a lot better at thinking. This takes study and practice. At first you need to carefully and consciously think about your thinking patterns. Slowly, with lots of

practice, you will develop new habits. Eventually you will use your new thinking habits without conscious thought.

Some General Considerations

1. Dealing With a Lack of Clarity

Suppose that you run into a problem situation that concerns you. At first the situation is probably not clear. There are many possible Goals. There are many possible Resources and Restrictions that might relate to any particular Goal. What do you do?

More efficient thinkers enjoy finding problem situations that are not clearly defined. They enjoy developing clearly-defined problems. They can make up many different problems from a problem situation.

Less efficient thinkers search for certainty and have difficulty dealing with unclear problem situations. They would rather ignore a problem situation than do the thinking required to deal with it. They are satisfied in making up just one problem from a problem situation.

2. Seeing Other's Points of View

Most problem situations can be looked at in many different ways. The same problem situation can lead to many different Goals. People have different points of view. Often there are many different ways to approach a problem or to achieve a goal.

More efficient thinkers are able to find and think about many different points of view. They can find strengths and weaknesses in different points of view. They can analyze evidence supporting different points of view. They can understand different people's points of view. They can argue both sides of an issue.

Less efficient thinkers do not consider alternatives. They have trouble understanding other's points of view. They form a first idea and hold to it. They are not open to other possibilities. They cannot think of arguments that might support a differing point of view.

3. Valuing Education and Good Thinking

Humans are naturally pretty good at solving problems. They can get better by study and practice. They can get better by learning the types of subjects taught in school. This is a key idea. Research on problem solving strongly supports the need to learn different subjects.

More efficient thinkers believe in the value of learning. The more you know, the better you can understand different kinds of problems. More efficient thinkers know that thinking can help a person to understand and solve problems.

Less efficient thinkers overvalue intuition. They may feel that school is not important. They may believe that thinking won't help one to understand and solve problems.

4. Attitude and Self Confidence

If you think that you can do something, then probably you can. Having self-confidence and a positive attitude are very important. Research suggests that these are two of the most important aspects of being good at solving problems.

More efficient thinkers have a positive attitude. They believe in the value of being a more efficient thinker. They have confidence in dealing with problem-solving situations.

Less efficient thinkers have a negative attitude. They lack self-confidence in dealing with problems.

Begin ✍✍ (You may want to write in your journal.)

Do some metacognition on the ideas discussed in the previous four sections. For each main idea, do you think of yourself as a "more efficient" thinker or as a "less efficient" thinker? Which are you best at? Which are you worst at? How can you tell? What are you doing about improving your efficiency as a thinker?

End ✍✍

Understand the Problem: Developing Goals

5. Searching for Goals

As we learned in Chapter 3, many problem situations do not have clearly stated goals. The same problem situation can lead to many different goals. But the choice of a goal is very important. The goal directs the problem-solving efforts. You don't have enough time and resources to solve every problem—to reach every possible goal.

More efficient thinkers can list many possible goals for a problem situation. They can examine such a list of goals and make good decisions about which goal or goals might be best.

Less efficient thinkers are not able to think of many possible goals. They often give little thought in picking a good goal to work on. They tend to have the attitude, "One goal is as good as another." Often they would rather that someone else tell them "the" goal rather than develop goals by themselves.

6. Revising goals

As you work to solve a problem, you gain a better understanding of the problem. Often you will find that your first understanding was not correct. You may

find that the goal you have selected cannot be reached with the resources you have available. Or, you may find that it is a poor goal.

More efficient thinkers give careful thought about what goal to try to achieve. If it becomes evident that they have selected a poor goal, more efficient thinkers revise their goal or select a different, better goal. They are flexible and open to change.

Less efficient thinkers continue to try to reach the initial goal, even if it is a poor goal. If the goal cannot be reached, they give up rather than select a more appropriate goal. They may have persistence, but they do not use their persistence in a wise fashion.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed above in Sections 5 and 6. Which of them apply to you? Which are your strengths and weaknesses? Think of examples where you exhibited the "more efficient" thinker habits.

Think about some problem situation you have dealt with recently. How did you decide on a goal? Did you change your mind once you started working on the problem? Did you revise your goal?

End ✍✍

Understand the Problem: Resources and Restrictions

7. Resources

You can't solve a problem without using resources. But what resources do you have that are applicable? This is often the hardest question to answer when working to solve a problem. You must know your own strengths and weaknesses. You must learn the types of resources you can bring to bear on different kinds of problems.

More efficient thinkers are good at brainstorming lists of Resources that might be useful in solving a problem. They are open to resource ideas suggested by others. They actively seek new resources.

Less efficient thinkers are not good at brainstorming lists of Resources. They prefer to deal with limited possibilities and are not open to other's ideas of possible resources. Often they conclude, "It can't be done with the resources available." rather than seek additional resources.

8. Restrictions

Every problem-solving situation has some Restrictions. Most often these are not clearly stated. Sometimes one assumes some Restrictions that don't really apply.

More efficient thinkers know a number of Restrictions that usually apply when dealing with problems. (For example, don't lie, cheat, or break the law.) However, more efficient thinkers know that sometimes it is appropriate or necessary to "bend"

or even break the Restrictions. (Is it ever okay to tell a "white lie" to avoid creating a still worse problem? When is it okay to try to get around the rules?)

Less efficient thinkers may not know the Restrictions that commonly apply. They may rigidly apply Restrictions that are not necessary or appropriate. They may lack flexibility in dealing with rules.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed above in Sections 7 and 8. Do they make sense to you? Give examples of problem situations where you were a "more efficient" thinker.

End ✍✍

Evaluating Possible Different Plans

9. Finding and Using Evidence

In most problems you have a lot of different Resources and Restrictions. You can think of a lot of different plans of action that use the Resources and remain within the Restrictions. Different people will think of different plans. You may think of several different plans. Which plan should be used?

More efficient thinkers seek evidence that challenges a proposed plan of action. What are the bad features of the plan? What might go wrong? What are possible bad outcomes? More efficient thinkers use this type of thinking to try to find a better plan of action.

Less efficient thinkers do not seek evidence that challenges a proposed plan of action. They ignore evidence that challenges a plan they have selected. They are not interested in hearing about things that might go wrong or possible bad outcomes.

10. Anticipating Outcomes

To solve a problem, you devise a plan of action and you carry out the plan. Carrying out the steps in the plan makes a change in the world. It uses some of your time and other resources. It may create new problems.

For example, suppose that you have a laundry basket of dirty clothes. Your goal is to have the clothes be clean. You decide that it will be cheapest and fastest to throw all of the clothes into one washing machine load. You don't think of the possibilities that (1) this may overload the machine, so that the clothes don't get clean and/or the machine will break and (2) your new red socks may run, and thus dye all of your white things pink.

More efficient thinkers can imagine the consequences of carrying out a course of action. They can detect side effects—new problems that might be created by a plan of action.

Less efficient thinkers do not consider possible consequences of a course of action. They often act rashly and seem surprised at unexpected outcomes.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed in Sections 9 and 10. Which seem most important to you? Give examples of problems where you were a "more efficient" thinker.

End ✍✍

Is the Problem Solved?

11. Have I Solved the Problem?

It often happens that you carry out a plan of action, but the problem is not solved. The plan of action may be a poor plan. Or, you may make errors in carrying out the plan. How can you tell if the problem has been solved?

When thinking about Goals, more efficient thinker asks, "How can I tell if I have achieved this Goal?" When devising a plan of action, more efficient thinker thinks, "How can I tell if I am making mistakes in carrying out this plan of action?" After a plan of action has been carried out, more efficient thinker examines the results to decide if the problem has been solved.

Less efficient thinkers carry out a plan of action and accept the results. They give little consideration to whether the results are correct or the problem has been solved.

This is one of the most important ideas in problem solving. It is very easy to have an error in one's planning on how to solve a problem. It is very easy to make a mistake in carrying out a plan. Thus, it is essential that you develop good skills at examining the results of your problem-solving efforts. Many students neglect this final step in solving a problem! They produce answers that are "obviously" wrong. But, they fail to think about their answers. Thus, they fail to detect obvious errors.

12. Unexpected Side Effects

The steps you take to solve a problem may lead to bad side effects. That is, new problems may be created. This can happen even if you think very carefully before carrying out your problem solving plan. Once the original problem has been solved, you have a new problem situation.

More efficient thinkers recognize that a new problem situation has been created by the process of solving a problem. They examine the new problem situation to see if it leads to new, important problems.

Less efficient thinkers do not think about the side effects of solving a problem. Once the plan of action has been carried out, they tend to forget about the whole thing.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed in Sections 11 and 12. Do they apply to you? Give examples in which you exhibited "more efficient" thinking. Give an example of a problem that you solved, where the results were an even harder problem being created.

End ✍✍

CHAPTER 6 SUMMARY

One way to get better at solving problems is to get better at thinking. More efficient thinkers make efficient use of their brains. They have a number of thinking skill habits that relate to the steps one follows in solving problems. Some very important good thinking habits include:

1. Valuing education and working to get a good education.
2. Having good skills in developing and revising Goals.
3. Having good skills in developing Resources and in knowing appropriate Restrictions.
4. Being good at thinking about possible outcomes from carrying out a plan of action.

You can become a better thinker and problem solver if you will identify your less efficient thinking habits and consciously work to improve them.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about some of your more efficient thinking habits. Perhaps you thought about the fact that you have some less efficient thinking habits. Perhaps you thought about a problem where you displayed more efficient thinking skills. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 6 ACTIVITY 1

   AN IDEA I HAD WHILE I WAS READING CHAPTER 6

   2. Write down and explain the idea.
   3. Explain why the idea interests you. Why did you remember this idea?
   4. How does this idea relate to things that you do outside of this class?
   5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in the earlier parts of the book.

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about several possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Consider the idea of changing the number of minutes between classes in your school. List several possibilities, such as decreasing the time by one minute, increasing it by one minute, or increasing it by five minutes. Give arguments for and against each possibility.

6. Consider making the periods in your school longer or shorter. This is somewhat similar to 5 above. In both cases we are working on the idea of dealing with alternate approaches to the same problem, seeing differing points of view, giving arguments to support each point of view. What would other students think? What would teachers think? What would parents think? Give arguments for and against each possibility.

7. Consider the list of 12 thinking skill habits listed in this chapter. Your problem is to order them on the basis of how good you are at them. The first item on your list should be the thinking skill habit that you are best at.

   One way to do this is to first break the problem into three smaller problems. For example, first put each item in the list into one of the three categories:

Category A: My best thinking skill habits. (Put two or three in this list.)

Category B: My mid-range thinking skill habits. (Put five or six in this list.)

Category C: My poorest thinking skill habits. (Put two or three in this list.)

Now continue by ordering the items on each of the shorter lists. As you do so, you may find that you have changed your mind and that an item needs to be moved from one list to another. Also, as you do this, be aware that you have used a strategy of breaking a big problem into smaller problems.

8. Consider one of the items that is near the bottom of the list that you created for Activity 7 above. Think about whether you would like to be better at this type of thinking. If not, pick some other item from the lower part of the list. Find one that is important to you.

   Then think about some ways that you could begin to do more of the "more efficient" thinker things related to this item. Make a brief written list. Think about some situations that will occur today or later this week when you will get a chance to practice these ideas. When you get a chance to practice, do so. As you do so, think about the fact that you are practicing an important thinking skill.

Chapter 7

Transfer of Learning

ORGANIZE YOUR THINKING
Learning is a way to prepare for the future. You can learn about a type of problem situation at one time and place. You can then use this knowledge to deal with a problem situation at a different time and place. When the two problem situations seem nearly the same to you, this is called a "near transfer" situation. When the two problem situations do not seem much alike to you, it is called a "far transfer" situation. • Near transfer is easy. Your mind does it automatically, with little conscious thought. • Far transfer is harder. You can get better at far transfer by study and practice. Getting better at far transfer will make you a more efficient learner.

Introduction

One of the most important ideas in problem solving is to build on your previous work. You have learned a lot. When a new problem situation comes up, you want to use ideas that you have learned before. But what if the new problem situation is a little different than the old?

For example, when you were very young you learned to tie your shoes. This probably took you a lot of time and effort. Of course, now it is easy.

When you get new shoe laces or a new pair of shoes, you automatically know how to tie them. These new "bow tying" problems are nearly the same as the bow tying problem you learned to solve when you were very young.

But how about tying a bow on a holiday package that you are wrapping? It is somewhat the same, but somewhat different. Or, how about tying a bow tie? It is somewhat the same, but quite a bit different. How about tying a square knot in a rope? It is somewhat the same, but somewhat different.

Sometimes it seems that a new problem situation is nearly the same as one you have encountered before. Your mind seems to automatically recognize the situation.

You remember what you did before and how well it worked. This helps a lot in dealing with the new problem situation.

Other times it seems like a new problem situation is really new and different. Your mind does not relate it to some problem situation that you have encountered before. You feel like you are faced by a completely novel situation.

Educational researchers have studied these situations very carefully. They have made up some words to use in talking about these situations.

In the first case, your mind quickly recognizes that the new problem situation is nearly the same as a problem situation that it has dealt with before. It does this without conscious thought. This quick recognition is called a **near transfer situation**. The brain transfers what it learned in the first situation to the new, present situation.

In the second case, your mind does not quickly and easily recognize that the new problem situation is similar to one that it has encountered before. The new problem situation seems far removed from what you have previously learned. This is called a **far transfer situation**.

Each person's mind is unique. Each person's experiences are unique. Thus, what is a near transfer situation for one person might be a far transfer situation for another person. For example, consider the following lines of poetry written by Joyce Kilmer.

In think that I shall never see

A poem as lovely as a tree.

In Joyce Kilmer's mind, a poem can be lovely and a tree can be lovely. The two different lovely things are closely related in his mind. Does your mind work like Joyce Kilmer's?

Begin ✍✍ (You may want to write in your journal.)

Think of several near transfer problem situations that you have dealt with in the past day. For example, perhaps you used a fork to eat some cafeteria food. Probably you have never used this particular fork before, and certainly you have never eaten that specific food before. You employed near transfer.

Think of a problem situation you have recently encountered that seemed like a far transfer situation to you. Pick one in which you were able to make a far transfer. For example, perhaps you used ideas from a school science class to solve a problem at home. Perhaps you used ideas from a math class to solve a problem in your health class.

End ✍✍

Some Brain Theory

Think about what happens when you come into a room full of people. You glance around to see if you recognize anybody. With little conscious thought, you

recognize your friends. Your visual system is very good at recognizing the people you know well.

Your brain is very good at recognizing patterns even when they are not quite the same as a pattern it has stored. You can recognize a friend even when your friend has a new haircut and different clothes. You can recognize a person you haven't seen for many years, even though they have gotten quite a bit older and their weight has changed. This happens quickly and easily, without conscious thought. It is a near transfer.

Your brain is very complex. It contains many billions of neurons. Each neuron can have connections to many thousands of other neurons. The neurons and the connections between the neurons store patterns. Your brain stores visual patterns, sound patterns, taste patterns, and so on.

Your brain is designed to be good at matching stored patterns with new patterns. You recognize a friend because your brain has stored a pattern of your friend's face. When you look at a person, your brain automatically begins to match what it is seeing with the stored patterns. If it detects a close match, you "recognize" the person. Sometimes your brain will make a mistake, and you will think that you recognize someone when you don't.

Also, recognizing a person and recalling their name are two different things. Your brain patterns for people's faces are stored in a different place than your brain patterns for names. Most people find that they are much better at recognizing a person's face than they are at remembering the person's name.

Begin ✍✍ (You may want to write in your journal.)

You can see and recognize a picture of a person, and then try to remember their name. Or, you can see a person's name, and then try to picture what they look like. Which are you better at?

Try an experiment. Picture one of your friends in your head, without thinking of their name. Can you do this? Then think of a different friend's name, without picturing the friend in your head. Can you do this?

Get together with a couple of other people from your class. Discuss the results of the name versus face activities. It what ways were your results alike? What were major differences?

End ✍✍

Brain researchers study the types of ideas discussed in the previous paragraphs. They have learned some things about the brain that can help you a lot. They have learned that the brain "learns" by building new connections among neurons. A brain gets "better" by building more connections and practicing using the connections. The more varied and "richer" the connections, the better the brain is at dealing with new, varied situations.

This helps us to understand the learning process. When you learn something new, your brain is building some new connections among neurons. The more the brain practices using these new connections, the better it gets at using them.

The Importance of Words

Words are very important in helping learning and transfer. Here is an example. When you were in grade school, you learned that data can be represented using a pie chart. An example is given later in this section. A pie chart looks somewhat like a pie cut into pieces.

What do the words *pie* and *chart* bring to your mind? When you think about the word *pie* do you think about food, dessert, cake, and being hungry? When you think about the word *chart* do you think about a poster hanging on the wall?

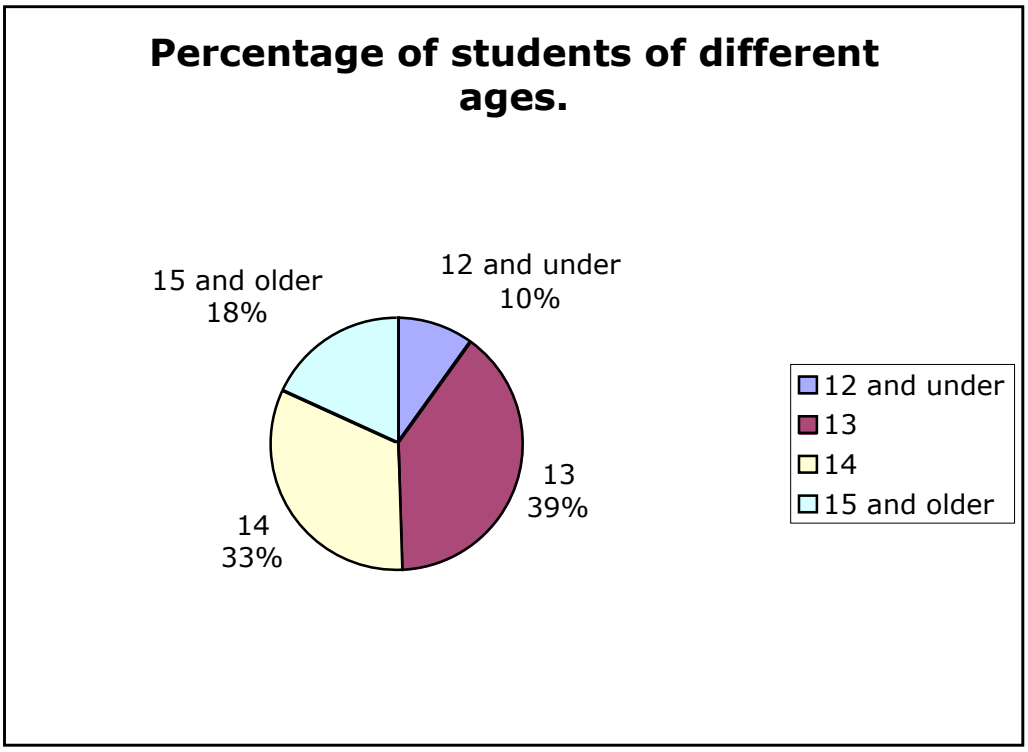
The expression *pie chart* is not a particularly good choice of words. It does not suggest ideas that are closely related to this way of representing information.

A better name for *pie chart* is *circle graph*. You are familiar with several types of graphs, such as bar graph, line graph, and pictograph. Each of these kinds of graphs is a way to represent information. They are all closely related. Thus, it helps to have their names be closely related. This helps you to transfer knowledge and skills from one type of graphing situation to another type of graphing situation.

A circle graph is useful in showing how something is divided into parts. For example, think about a school that has 250 students. Most are 13 or 14 years old, but some are younger and some are older. What percentage of the students fall into each age group?

A circle graph gives a picture of this data. The human visual system is very good at processing this type of picture information. So, a circle graph is useful in representing "parts of a whole" types of data.

Age Range	**Number of Students**
12 and under	25
13	98
14	82
15 and older	45
Total	250



Learning for Near and Far Transfer

This section contains a little bit of **learning theory**. It tells how your brain works when it learns new things. You can think about your own learning processes. You can learn how you best learn new things. It is very important that you understand how to help yourself learn.

Here are two different approaches to learning something:

Type 1 Learning—Learning for near transfer: In learning something new, focus your attention just on the new material. Work to build just a few neural connections. Practice using these connections over and over again, so that you can do the new thing very rapidly and accurately. Build a few, very "strong," well practiced, neural connections.

Type 2 Learning—Learning for far transfer: In learning something new, focus your attention both on the new material and lots of different things that seem related. Work to build a large number of neural connections. Connect the new ideas to lots of different things that you already know. Build a very large, "rich" set of neural connections.

The first approach is very important if you need to be able to do something rapidly and accurately, perhaps with little conscious thought. You practice the information or skill over and over again. Eventually you get very good at it. You can respond rapidly and accurately to a situation that is nearly the same as the situation you have studied.

Of course, it takes a lot of time to do this. Also, you are not building neural connections to other ideas that you know. So, your brain is less apt to recognize a new situation as being "near" to the old situation that you have learned so well.

The second approach helps far transfer. When your brain encounters a new problem situation, it searches for stored patterns that are somewhat similar to the new situation. The richer and more varied the neural connections to the old problem situation, the more apt your brain is to find that the patterns are related. But of course, it takes a lot of time to build this rich and varied set of neural connections.

In some learning situations it is necessary to take the first approach. Very good examples come from the "basics" in sports. To perform well, you must train your brain to respond rapidly and accurately to certain situations that occur over and over again.

But in most learning situations, a balance between the first and second approach is important. You get better at problem solving by getting better at transferring your learning to new problem-solving situations. You improve transfer of learning by carefully and consciously building a rich and varied network of neural connections.

Begin ✍✍ (You may want to write in your journal.)

Think about Type 1 Learning and Type 2 Learning. Which do you think you are better at? Why?

Which do you think is more useful in learning to solve school problems? Why?

Which do you think is more useful in learning to solve problems that occur outside of school? Why?

End ✍✍

An Example of Type 1 and Type 2 Learning

The math teacher knows that circle graphs are very important. But many students find that it is hard to learn how to draw a circle graph. You need to work with percentages. This requires long division. You need to know that a circle contains 360 degrees. You need to figure out different percentages of 360 degrees. This requires multiplication and working with decimals. You need to learn how to use a protractor to measure degrees and a compass to draw a circle.

Because of all of this, the math teacher places most of the instructional effort on having you learn how to make a circle graph. This is like the Type 1 Learning described in the previous section. It prepares you to accomplish the specific task of making a circle graph.

Also, you know that you are going to be tested on circle graphs. So, you practice on them until you know that you can pass the test. You place considerable emphasis on Type 1 Learning. You have a (near transfer) goal of being able to draw a circle graph on the next test.

Now think about what happens in your social studies class a few weeks or months after you have studied circle graphs in math. The teacher is talking about

income levels. Perhaps the class is looking at data about how many people earn less than $10,000 per year, how many earn between $10,000 and $15,000, and so on. Does it occur to you that this would be a good place to use a circle graph?

For some students, the answer is clearly "no." For some students, the income problem situation in a social studies class is a far transfer situation from the circle graph problem situation in a math class. Their learning efforts in the math class were so concentrated on the Type 1 Learning, that little time was spent on Type 2 Learning. They did not spend time and effort building a rich and varied set of neural connections. Their brain fails to detect that the pattern of data in the social studies class is like the pattern of data in the math class. Thus, their brain is unable to realize that a circle graph would be useful in the social studies class.

Begin ✍✍ (You may want to write in your journal.)

The need to draw a circle graph can occur in many different courses. Make a list of situations where a circle graph would be useful. Is drawing a circle graph a primitive for you?

How long do you think it would take you to draw a seven-piece circle graph, starting with the seven pieces of data? You might want to do an experiment. Make an estimate of how many hours per week you spend per week in each of the following categories. (The total number of hours in a week is 7 x 24 = 168.) Then draw a circle graph of your data. Time how long it takes you.

1. Sleeping.
2. Going to school.
3. Watching television, listening to the radio, and listening to recordings.
4. Eating.
5. Talking to friends.
6. Getting to and from places (transportation).
7. Miscellaneous other activities.

End ✍✍

Concepts and Procedures

The circle graph example illustrates a very important idea about learning. It is an idea that we talked about in an earlier chapter when we defined the idea of a primitive. There are two very different things to learn about circle graphs:

1. The "concept" or underlying ideas in a circle graph. A circle graph gives a picture of the "parts of a whole." It is a good way to represent the pieces of something, so a person can see their relative sizes.
2. The steps (processes, procedures) that you must carry out in order to draw a circle graph. To draw a circle graph by hand requires a good working knowledge of quite a bit of math.

The human brain is quite capable of learning the concepts of a circle graph and how to do the procedures to draw a circle graph. However, a computer can easily, quickly, and rapidly convert data into a circle graph. The computer can do the "procedure" part of drawing a circle graph. This means that drawing a circle graph can become a primitive for you if you learn the mental concept of circle graph and have access to a computer. A circle graph is a good example of a computer primitive.

Begin ✍✍ (You may want to write in your journal.)

Is it easier for you to draw a circle graph or a bar graph? (In a bar graph, the heights of the bars represent the numbers to be displayed.) In what ways are the concepts of a circle graph and a bar graph nearly the same for you? In what ways are they different?

Have you used a computer program that can draw a circle graph? Usually, the same program can also draw a bar graph and a line graph. Once your data is entered into the computer, just a few key strokes are needed to output it in any one of the graphical forms. How might this help you to solve problems?

End ✍✍

Learning to Increase Far Transfer

How many times have you sat in a school class and thought, "I wonder what good this is to me? It doesn't seem to have much to do with me and what I am interested in."

Such questioning is a good start in increasing far transfer. As far as your brain is concerned, everything can be related to everything. A poem and a tree can be closely related. But it is up to you to tell the brain what neural connections to build. You can do this by making a conscious effort to do so. You "tell" your brain to build neural connections by "thinking" about how things are related. If you want neural connections that relate a poem to a tree, you must consciously think about how a poem and a tree are related.

Only you can make up a good answer to the question, "I wonder what good this is to me? " Everything you learn can be related to other things you already know. The good thinker consciously builds many neural connections. The good thinker finds many answers to the "What good is this?" question.

Begin ✍✍ (You may want to write in your journal.)

Let's practice a little. Think of ways in which a cat and a dog are related. Then think of ways in which a cat and a tree are related. Then think of ways in which a dog and a tree are related.

Suppose that you had started with the task, "Think of ways in which a dog and a tree are related." Would you have produced the same connections as you got in the previous paragraph? Why, or why not?

End ✍✍

Let's go back to the circle graph example. The math teacher stresses that there are several important ideas (underlying principles) in circle graphs:

1. In many problems, it is important to think about "parts of a whole."

2. A circle graph is a good way to represent parts of a whole.

You can listen to what the teacher is saying. You can memorize the expressions "parts of a whole" and that a circle graph is useful in representing parts of a whole. You can concentrate on the Type 1 Learning that will help you pass a test in which you have to draw a circle graph.

But there are two things wrong with this approach. First, little Type 2 Learning will occur. You will not develop the rich and varied neural connections needed to help far transfer.

Second, you will be spending your time learning to do things that a computer can do! A computer can take a table of data and draw a circle graph of it. A computer can do this accurately and rapidly. A computer can do it far more accurately and rapidly than a well-trained human.

Remember the question we asked early in this book. If a computer can solve or help solve a type of problem, what should a student learn about solving this type of problem? We are beginning to develop an answer. In the circle graph example, there are two different types of learning going on. The Type 1 Learning helps the brain to become machine-like. It concentrates on learning a procedure. It helps the brain to become fast and accurate at doing the procedure. But often the procedure is one that a machine can accomplish much better than a human.

On the other hand, the Type 2 Learning helps the brain learn to respond to new and varied situations. It stresses learning concepts or underlying principles. It stresses how the general ideas can be used in a wide variety of problem situations. Such learning promotes far transfer. Humans are very good at this. A human can learn that a poem and a tree are related through both being lovely. A human can know and understand what it means for something to be lovely. Humans are far better than computers at this type of task.

CHAPTER 7 SUMMARY

You can get better at far transfer by study and practice. When you are learning how to solve a new type of problem, think about:

1. What are the underlying concepts or principles?

2. How are these concepts related to other things you already know? (Do metacognitive thinking that will increase far transfer.)

3. What are the procedures needed to solve the problem?

4. Can a computer or other machine help carry out these procedures?

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought that "transfer" is an interesting idea. Perhaps you wondered why some teachers place so much emphasis on learning for near transfer. Perhaps you thought of ways that a cat and a poem are connected. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.
    1. Make a title for this journal entry. Your title might look like this:

    _____

    CHAPTER 7 ACTIVITY 1

    AN IDEA I HAD WHILE I WAS READING CHAPTER 7

    2. Write down and explain the idea.
    3. Explain why the idea interests you. Why did you remember this idea?
    4. How does this idea relate to things that you do outside of this class?
    5. What else do you think about when you think about this idea?
2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

    In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

    far transfer situation

    learning theory

    near transfer situation

3. Make up a short quiz of lower-order thinking skill questions for this chapter. The idea of lower-order thinking skills is discussed in the Glossary. Include correct answers with your questions.

   Often a lower-order skill question has only one correct answer. It asks for a simple fact or a low level of understanding) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. The idea of higher-order thinking skills is discussed in the Glossary.

   Think about several possible correct answers for the questions you write. Remember that a good higher-order skill question is likely to have many different correct answers. It asks about complex relationships. It may ask a person to put together two or more ideas. Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. This is a journal writing activity. Select four different subjects that you are taking.
   1. Make a title for this journal entry. Your title might look like this:

      _____

      CHAPTER 7 ACTIVITY 5

      CONCEPTS AND PROCEDURES IN FOUR SUBJECTS

   2. For each subject, give an example of a concept and an example of a procedure that is important to learn in that subject.
   3. Which of the subjects seems to spend the most time on learning concepts? Why do you think the subject does this?
   4. Which of the subjects seems to spend the most time on procedures? Why do think the subject does this?

6. This is a journal writing exercise. You know how to multiply big numbers together. For example, you know how to do the calculation:

   5,293 x 718

   Perhaps you know the concept that multiplication is a fast, shorthand way to do repeated addition. (Imagine adding up a column of 5,293s that is 718 lines long!)

   While you were in grade school, you learned a paper and pencil procedure to do multiplication of whole numbers. If you are like most students, you have spent many dozens of hours practicing this multiplication procedure. You can do it fairly rapidly and fairly accurately.

1. Make a title for this journal entry. Your title might look like this:

_____

CHAPTER 7 ACTIVITY 6

TRANSFER IN MULTIPLICATION

2. Discuss how the things you have learned about multiplication of whole numbers transfer to learning to do multiplication of decimal fractions such as:

   3.73 x 89.413.

   Your discussion should talk about both concepts and procedures.

3. Discuss how the things you have learned about multiplication of whole numbers transfer to learning to do multiplication of fractions such as:

   3 5/6 x 8 3/4

   Your discussion should talk about both concepts and procedures.

7. One very important idea in problem solving is self-confidence. Some people "know" that they are good at solving problems. When they encounter a new problem situation, one of their Resources is self-confidence. This self-confidence is a resources that transfers to every problem situation.

   Think about your level of self-confidence as a problem solver. Is it as high as it could be? What might make it higher? Think of an idea for improving your self-confidence as a problem solver. Practice it several times a day.

Chapter 8

Modeling

ORGANIZE YOUR THINKING
A model, such as a scale model, can serve in place of the "real thing" to help you solve problems. There are different ways to model (represent) a problem. One way is in your head—a mental model. A second way is by talking—a verbal model. A third way is using writing and pictures. Still another approach is to model a problem inside a computer. You can get better at problem solving by: • Learn a number of different ways to model a problem. • Practice using different models. Learn when one is better than another for you. • Learn to develop and use computer models of problems.

Introduction

In order to solve a problem, you must understand the problem. You must represent the problem so you can work on it. You must pick out important aspects of the problem. You must think about how the important parts relate to things that you know.

A representation of a problem is called a **model** of the problem. There are many different ways to model a problem. For example, you might build a scale model or draw a picture to represent a problem. You can think of a blue print of a building as a model of the building. You might model a problem using words or mathematics. Each different type of model has certain advantages. A type of model that is very useful for one kind of problem might not help on a different kind of problem.

In this chapter we will examine a number of different types of models. Each type of model has certain especially useful features. We will begin to talk about how computers can be used in modeling problems. Use of computers in modeling is a very powerful aid to solving many different kinds of problems.

Mental Models

You can solve many problems in your head. You think about a problem.. You consider different things that you might do to solve the problem. In your mind's eye you can see the steps needed to reach the goal. You imagine carrying out these steps and the possible results. As you work on the problem, new ideas occur to you. You make changes in your mind.

Think about a problem that you dealt with yesterday. Get the problem clearly in mind. (Don't read the next paragraph until you have a specific problem in mind!)

Pretend that you are explaining the problem to yourself. Represent the problem using words and pictures in your mind. What feelings does the problem bring to mind? Perhaps you can even recall smells and tastes associated with the problem.

You have just created a **mental model** of a problem. It is a mind picture—a mental representation. A model is not the same as the object or idea being modeled. A mental model of a problem is not the same as the problem. But a model can represent some of the important parts of a problem. It can help you to solve a problem.

You can use a mental model to think about a problem. You can use it to consider possible actions. In your mind's eye you can see what might happen if you carry out the actions. Mental modeling is part of thinking. It is very important in problem solving.

Begin ✍✍ (You may want to write in your journal.)

Do some metacognition about the mental model you formed earlier in this section. Was your mental model mainly pictures? Was your mental model mainly words and sounds? Sometimes a "picture" mental model is most useful. At other times, a "words and sounds" mental model may be most useful.

Think about a cow. When you think about a cow, does a picture of a cow form in your head? Does a "mooing" sound form in your head? Does the smell of a barnyard form in your head? The mental models that you form depend on the experiences and training you have had.

Think about a cold, windy day. Do metacognition on your mental model. Then think about being lost in a dessert. Do metacognition on your mental model.

End ✍✍

Your mind is very powerful. It can form a mental model of anything that you want to think about. If you want to think about a cloud, your mind forms a mental model of a cloud. If you want to think about a polka dotted cow, your mind forms a mental model of a polka dotted cow. With a little effort, you can even form a mental model of polka dotted milk from such a cow!

Verbal Models

It is very helpful to be able to share your mental models with other people. One way to do this is by talking. You can form a **verbal model**. You can use spoken words and other sounds to represent your mental model. A verbal model may also include "body language." A great deal of information is communicated through facial expressions, hand movements, and so on. Sometimes we will call a verbal model a **verbal/body language** model to emphasize that both sounds and body language are involved in the communication.

Probably you are good at talking. However, sometimes it is hard to find the right words. Can you find words to describe the taste of good food? Can you find words to describe what it is like to be with a good friend? Sometimes it is not easy to give a good verbal model of what is in your head. It is helpful to have a large vocabulary!

Thinking and talking are closely related. When you are thinking, you are doing silent talking. Talking out loud helps you to organize your thoughts. It is a way of practicing your thinking. You can get better at thinking by getting better at talking. Words are an aid to thinking. That is why vocabulary and talking using the vocabulary are stressed in this book.

Researchers have found that talking about what you are learning is a powerful aid to learning. Teachers have known this for a long time. They learn a lot about the subject they teach by talking about it with students. You can learn by explaining new ideas to your friends.

Begin ✍✍ (You may want to write in your journal.)

This is a game that can be played in small groups. Get together with two other students in the class. One person is to be the "sender" and the other two are to be the "receivers." The sender forms a mental model of a person, place, or thing. Then the sender begins to give a verbal model of the object, but without naming it.

The goal is to give a very good verbal model. As soon as a receiver is sure they know the object, they write it down. The game ends when both receivers have written down the name of the object. When a game ends, check to see if the answers are correct. Talk about which clues were most helpful. Then have someone else become the sender.

The same activity can be used with the sender drawing a picture. It can also be played using non-verbal modeling—just acting out the object. Several television game shows use these ideas.

End ✍✍

Written Models

The invention of reading and writing is undoubtedly the single most important event in the history of education. Writing, using letters, digits, punctuation, diagrams, and so on, is a way to model spoken language. We will call this a **written symbolic**

model, or simply a **written model**. When you write, you are creating a written model. When you draw a picture of an object, you are making a written model of the object.

The process of writing is very closely related to thinking. Writing helps your brain to think. Writing helps you to organize your thoughts. Writing is a very important aid to problem solving. To be a good writer, you must be a good thinker.

Writing has additional values. It is an aid to your memory. Thus, you can form a written model that is much more complex than you can hold in your active, conscious memory. This written model can be stored for later use. Copies can be made for other people to use.

A Brief History of Writing

Researchers have discovered drawings on cave walls that are more than 15,000 years old. At that time all people got their food by hunting and by gathering wild fruits, vegetables, and grains. The cave wall drawings can be thought of as written models. Perhaps they helped people to remember successful hunts and other special events.

More than 10,000 years ago some people began to be farmers. They learned to plant crops and raise farm animals. But this led to many hard problems. When do you plant your crops? When do you harvest your crops? How many animals do you have? (Did a wolf get one last night?) How much grain do you have in storage? Is there enough to last through the winter?

Numbers and written languages were developed to help solve these problems. The very earliest written languages used pictures to stand for ideas or words. A picture of a sheep could stand for a sheep. A simple stick figure of a person could be used to represent a person.

But how do you represent an old person, a child, a baby, a female baby, and so on? How do you represent your relatives and their relationships to you? It is easy to see why languages contain so many words.

The development of writing led to a major turning point in education. Every community needed some people who could read and write. Every community needed to write down historical records. But it takes a long time for a person to learn to read and write. It requires having a teacher to help you learn. The teachers needed to have a great deal of knowledge. Students needed to go to school to learn to read and write.

It is easy to see why math was so important to early farmers. One good example comes from the history of people living along the Nile river in Africa. Each year the river flooded and wiped out boundary markers. Each year it was necessary to figure out the boundaries of the fields. The word "geometry" means "earth measure." Geometry was needed to survey the land, to figure out the boundaries.

Have you ever wondered why there are so many different subjects in school? Why do we have art, music, health, physical education, math, science, and so on?

Each subject deals with different kinds of problems. The problems in art are quite a bit different than the problems in biology or in health. There is a great deal known about the problems in each subject.

People working in a subject want to write precise descriptions of the problems. They want to write precise descriptions of how they try to solve the problems. They want to give examples of the problems that they know how to solve. This leads each subject to develop its own special words and its own special symbols. This helps the workers in the field to write very precise written models for use in their field.

One major goal in each subject you study is to learn to make verbal and written models for the problems in that subject. This means that it is very important to learn the vocabulary. It is very important to practice talking and writing about the ideas in the subject.

Begin ✍✍ (You may want to write in your journal.)

Think about the problem of communication faced by musicians. They have developed musical notation and special vocabulary to help them form symbolic models. Think of some other subject that uses special notation and words. Give some examples of the notation and special vocabulary.

End ✍✍

Written Models Help Your Mind to Store and Process Information

The neurons in your brain do two different things. They **store** information and they **process** information. Your mind is both a storage device and a processing (a thinking) device.

This is a key idea. It suggests two kinds of aids to the mind. One kind is a storage aid. The other kind is a processing aid. For example, a dictionary is a storage aid. A hand held calculator is a processing aid.

It is possible to have a combined storage and processing aid. For example, writing, and paper and pencil, are a storage aid. But they are also a processing aid. Writing helps you to organize and then reorganize your thoughts.

Paper and pencil arithmetic provide another example. Think about doing a paper and pencil long division. You make use of writing as a temporary storage aid. You also use the writing to help you process the math symbols.

Begin ✍✍ (You may want to write in your journal.)

Think of some problems where you have used aids to your brain's storage capacity. For example, do you write down the addresses and phone numbers of your friends?

Think of some problems where you have used aids to you brain's processing capabilities. For example, do you make use of a hand held calculator?

End ✍✍

Scale Models

There are many other kinds of models that can help you to solve problems. For example, you have seen **scale models** of cars, airplanes, and houses. A scale model of a office building can be used to help design a office building. What will the office building look like when it is built? How will it fit into the landscape? Will people find the office building attractive?

Airplane designers build scale models of airplanes. A scale model of an airplane can be used in a wind tunnel to test the shape of the body and wings. How much air resistance will there be? This is much cheaper than building an entire airplane and then seeing how well it flies. Also, it is much safer!

Begin ✍✍ (Please write in your journal.)

Please do the following journal writing activity. Use a title line such as the following.

EXAMPLES OF USING KINDS OF MODELS

1. Give an example of a time when you used a mental model to help you solve a problem.
2. Give an example of a time when you used a verbal model to help you solve a problem.
3. Give an example of a time when you used a written model to help you solve a problem.
4. Give an example of a time when you used a scale model to help you solve a problem.
5. Think of other types of models that you have used to help you solve a problem. For each, give an example of the type of problem that you were solving. For example, a budget is a model used to deal with a money problem. A map is a model used to help find out how to get some place. A recipe is a model used to help solve a food problem.

End ✍✍

Mathematical Modeling

You may have wondered why you have to take so much math in school. The reason is that math is a very general-purpose aid to modeling many different kinds of problems. How much money do you have with you right now? The answer—a number—is a **mathematical model** for your money.

Think about a carpenter building a table. The table will have a rectangular top with a molding around it. The carpenter is thinking about how much material will be needed. Here is a written model for this problem.

The area of the tabletop is the length times the width.

The perimeter of the tabletop is twice the length plus twice the width.

Now think about a farmer who is planning a field that needs to be of a certain size. The farmer is planning a rectangular field. Here is a written model for this problem.

The area of the field is the length times the width.

The amount of fencing needed to enclose the field is twice the length plus twice the width.

Mathematicians have spend a lot of time thinking about such written models. They notice that the two written models are nearly the same. Consider the following math formulas.

Area = Length x Width

Perimeter = 2 x Length + 2 x Width

These math formulas are a mathematical model for the carpenter's problem and the farmer's problem. But even these simple formulas are too "wordy" if they are to be written over and over again. So, mathematicians have developed abbreviations for these formulas.

$A = LW$

$P = 2L+2W$

These examples illustrate two very important points:

1. The experts in a field develop special vocabulary, special notation, and special abbreviations to represent the written models of their field. So, if you want to read and use the models in a special field, you need to learn the vocabulary and notation of that field.
2. The same math model can be used for a number of different problems. A set of math formulas can be a model that helps solve a problem for a carpenter or a farmer. This helps in transfer of knowledge and problem-solving skills among fields.

But there is still one more important point to make about this example. The math model for a rectangle does not say anything about the material to be used. It says nothing about the type of wood the carpenter will use. It says nothing about the type of fencing material the farmer will use. The formulas are a model for just two aspects of a rectangle—its area and the distance around it.

This is a very important idea. A model is a representation of certain aspects of an object. If you want to study these aspects, the model may help. However, the object being modeled has many features that are not in the model. If you want to study these features, the model will not help.

Begin ✍✍ (You may want to write in your journal.)

Give several examples of uses of the math model formulas for a rectangle. For each one, give at least two examples of important features that these math formulas do not include.

For example, the area formula is a useful model in working on the problem of painting the floor of a room. But the formula does not talk about the color to be used, what quality of paint to use, how long it will take to dry, and so on. The perimeter formula is useful in fencing a parking lot. But it does not say anything about the height of the fence, the type of material to be used, or how good the fence will look.

End ✍✍

Computer Models

The computer was invented as an aid to doing math. The idea was that certain types of math formulas could be stored in a computer. The computer could automatically do the work of using the formulas. (Notice that the computer was invented as a **storage** and **processing** device.) The goal was to make it much easier to solve problems that require a great deal of computation.

Earlier in this chapter we talked about building a scale model of an airplane. We talked about using a wind tunnel and the scale model to test the design of a new airplane. In recent years scientists have developed another way to test the design of an airplane. They write formulas that describe the shape of the airplane. They write formulas that describe how the airplane will perform at different speeds. The formulas use math symbols. These math symbols can be put into a computer. This is called a **computer symbolic model**. To save words, we will usually just call it a **computer model**.

With a computer model, scientists can do the same types of tests that they can do with a scale model and a wind tunnel. But in many ways a computer model is much better than a scale model. For example, it is easier to change a few formulas than it is to rebuild a scale model or build a new scale model.

Soon after the first computers were built, people began to think of lots of uses outside of math. They realized that a computer model could be used on many different kinds of problems. As computers have gotten cheaper and more available, more and more uses have been developed. But one simple idea remains true. A computer is an aid to the storage and processing of symbolic models.

Why Are Computers So Important?

A mental model is very useful in solving problems. A mental model is easy to change. You just "think" it different. You change the pictures in your head. Then you can think about solving a problem using the new mental model. You use your mind for both storage and processing in solving problems.

However, your mind has limitations as a storage device, because it can easily forget things. It has limitations as a processing device, because it gets bored and can easily make mistakes. Thus, it is important to have aids to your mind.

A written model is harder to create than a mental model. Also, it is harder to change than a mental model. But a written model is a good aid to storing and

processing information. Also, it is more permanent, and it is possible to make a lot of printed copies. A written model of a problem can be shared with other people. This helps a number of people to work together on a problem.

It would be nice to have something that combines some good features from mental models and written models. You want to be able to build models that are easy to change, like a mental model. But you want something that will help your mind in storing and processing information. Also, you want to store information in a permanent, transportable, shareable form.

The electronic digital computer is an answer. A computer is an aid to both storage and to processing. A computer model can be easy to change. A computer can process information that is in a computer model. Information in a computer can be shared and transported. These features make computers important.

For example, suppose that you are working on a problem of writing a report. The goal is to do a very good job of writing. This means that you will want to read your report very carefully. You will want to revise it so that it says exactly what you had in mind. (You want your final written model to be a good representation of your mental model.) You also want to correct all errors in spelling and grammar that you find.

Now suppose that you have a computer and a word processor to help you solve the writing problem. You type your report into a computer by using a word processor. With a computer, it is easy to make changes in your report. It is easy to insert new sentences to make the report clearer. It is easy to rearrange paragraphs if this is necessary. It is easy to correct errors in spelling and grammar.

Indeed, the word processor may contain a spelling and grammar checker. A spelling checker looks up every word in a dictionary. It does this rapidly and automatically. This is a type of processing that computers can do very well.

Now you can begin to see the value of using a computer model. A computer model is easy to change. And, the computer itself may help you to decide what changes to make!

Some More Uses of Computer Models

The rest of this book is about computer models. You will learn about some of the kinds of problems that can be represented by computer models. Here are a few key ideas:

1. Some aids to computer modeling are very easy to learn how to use. A word processor is a good example. It is also easy to learn to use a computer to do graphics and to work with databases.
2. Some aids to computer modeling are useful in solving a wide variety of problems. A database is useful in every subject that you might study in school.

3. Some aids to computer modeling are very specialized. For example, there are computer programs that help a person write music symbols. Think of this as a "music notation" processor, sort of like a word processor designed for use in music.
4. Many computer programs have been written to solve some important problems that occur over and over again. For example, consider the problem of finding spelling and typing errors in your writing. This is the problem that a spelling checker is designed to help solve. This is an aid to your mind's processing abilities.

   Similarly, a computer can do much of the processing in solving many different math and science problems. There are thousands of computer programs that have been written to do this type of processing.
5. A computer can be very helpful in solving a lot of different kinds of problems. But there are many problems that a computer cannot solve. It is important to understand limitations of computers.

The key to using a computer to help solve a problem is computer modeling. It is easy to see how to model a dictionary in a computer. One just stores all of the words in the computer memory. It is easy to see how to model the processing of checking for spelling errors. One just has the computer look up every word in its dictionary. Even here, however, you can begin to see some computer limitations. Consider the sentence, "I went two the store." A spelling checker will not tell you that you that "two" is incorrect in this sentence. The problem of developing a computer program to detect such errors has proven to be very difficult.

There are other much more important problems were computers are of limited value. How do you model human feelings in a computer? How do you model human values? How do you model the beauty of a setting sun or a silent evening? How do you model being in love? There are many things that cannot be modeled very well in a computer. A computer is not too useful in solving problems involving human values, feelings, and beauty.

Computer modeling is a very important idea. It is a powerful aid to problem solving. There are many problems that can be solved by computer modeling. But mental models are still the most important. Problem solving begins in your mind.

CHAPTER 8 SUMMARY

Modeling is a key part of problem solving. Mental modeling is most important. However, different types of models are useful in working on different aspects of a problem. A complex problem may require you to use a variety of different models.

Many different kinds of models can be represented inside a computer. Computer modeling may take advantage of a computer's:

1. Storage capability..

2. Processing capability.

A well designed computer model is easy to change. This helps in working on hard problems.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how your mind seems to be good at developing mental models. Perhaps you realized that you had not thought about modeling the way this chapter presents it. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    _____

    CHAPTER 8 ACTIVITY 1

    AN IDEA I HAD WHILE I WAS READING CHAPTER 8

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things that you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

    In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

    computer symbolic model (computer model)

    mathematical model

mental model

model; modeling

scale model

written symbolic model (written model)

verbal model

verbal/body language model

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Do you have any loose change with you? The word "quarter" is a model for a particular piece of metal. But the same word has many other meanings. List a number of meanings for the word. When you are talking to someone and they say the word "quarter," how can you tell which meaning they have in mind? Do you think a computer could do this?

6. Imagine that you have a fresh apple in your hand. The apple is firm, juicy, and just the right ripeness. Imagine how good the apple will taste as you bite into it. Make a mental model of an apple in your head.

   What color of apple did you think of? How big an apple did you think of? As you thought of this apple, did you think of anything else? For example, did you think about other kinds of fruit?

   Now give a number of examples of models of different aspects of an apple. For example, 14 ounces is a model of the weight of a rather large apple.

7. If a computer model can be developed for a problem, does this mean that a computer can solve the problem? Give examples and/or arguments to support your conclusion.

8. We use the Hindu-Arabic numerals 1, 2, 3, etc. The Romans used the numerals I, II, III, IV, V, etc. Compare and contrast these symbolic systems for representing math problems. For example, which is easier to learn? Which is best for doing very simple addition? Which is best for doing long division?

9. In what sense is a budget a model? Give a specific example of a problem that you have solved by making use of a budget model.

10. Consider the saying, "The map is not the territory." Think of a map as being a model. For example, a "globe" is a representation of the world. Explain some possible meanings of the saying.

Chapter 9

General Purpose Computer Tools

ORGANIZE YOUR THINKING

Some of the basics of education include reading, writing, and arithmetic. These are "tools" that help you to understand and solve many different kinds of problems.

There are some computer tools that are useful in solving a wide range of problems. Examples of these general purpose tools include:

- Word processor (modeling using writing).
- Database (storing and looking up information).
- Graphics (modeling using diagrams and pictures).
- Spreadsheet (math modeling).
- Networking (connecting computers with databases, people, and other computers).

Introduction

In some ways a computer is closely related to reading, writing, and arithmetic. It is an aid to the human mind. It is a general-purpose aid to problem solving.

You know that a computer is not a substitute for good thinking. However, on many problems a good thinker who knows how to use a computer has a big advantage. Remember how we defined "a smart person" in Chapter 2? A smart person knows how to use tools as an aid to solving problems. You can learn to use a variety of general-purpose computer tools. This knowledge will help you to solve problems.

Some computer tools are extensions of tools that existed before computers. A word processor is an aid to writing. One way to think about a word processor is as an electric typewriter with a memory. In some ways it is more useful and powerful than paper and pencil. In other ways it is less convenient and useful.

Numbers, arithmetic, and a hand held calculator are a very useful aid to solving many different problems. They help you to develop math models of problems and to carry out the arithmetic in these math models. A type of computer program called a **spreadsheet** has these same features. It is a general-purpose aid to developing some types of math models. The spreadsheet was first developed to help solve business problems. Now it also has many other uses.

You know that it takes a lot of time and effort to learn reading, writing, and arithmetic. But it is well worth the effort, because they have so many uses. You will find that some general-purpose computer tools are easy to learn how to use. Others will take you a great deal of time and effort. But if you need to solve the types of problems that the computer tool is designed to help solve, it will be well worth the time and effort.

It is easy to learn to use a word processor. One reason is that the **human-machine** interface makes it easy. If you know how to use a typewriter, you know most of the things needed to use a word processor. A word processor is designed to be easy to use and easy to learn how to use. It is designed to be **user friendly**.

Begin ✍✍ (You may want to write in your journal.)

This activity assumes that you have used a word processor. Name some ways in which a word processor is better (more user friendly) than pencil and paper as an aid to writing. For example, it is easier to correct mistakes. Name some ways in which pencil and paper are better (more user friendly) than a word processor as an aid to writing. For example, paper and pencil are much more portable.

Now think of a word processor that also contains a spelling checker. Compare and contrast it with pencil, paper, and a dictionary as an aid to writing.

Now think of a word processor that contains a grammar checker. Would this help you to be a good writer?

End ✍✍

In this chapter we look at a several general-purpose software tools. The chapter is not designed to teach you how to use these tools. (Other people have written books for that purpose.) We assume that you have already used some of these pieces of software. You will learn to use others if you decide that is worth your while.

Begin ✍✍ (Please write in your journal.)

Please do the following journal writing activity. Use a title line such as the following.

GENERAL PURPOSE SOFTWARE

1. Make a list of general-purpose problem-solving pieces of computer software that you know how to use. Examples might include a word processor and a program for drawing graphs. For each one, give examples of the kinds of problems the software helps to solve.
2. Make a list of some general-purpose pieces of computer software that you have heard about but don't know how to use. For each one, give examples of the kinds of problems that you think the software helps to solve. For example, perhaps you have heard of a spreadsheet but never used one. It is useful in solving business and math problems.

End ✍✍

There are thousands of computer programs that help solve problems. Some are especially designed to solve just one specific type of problem. For example, there are computer programs that can solve chess problems. (What moves do you make to win during the next three turns?) There are computer programs to train astronauts to fly spaceships..

This chapter talks about some of the more versatile computer software. It discusses software with the following features:

F1. The software is useful in helping to solve many different kinds of problems from many different fields. It may be useful in every subject you study in school.

F2. The software is useful in working on the kinds of problems in which one needs to make many changes. The computer helps you to try different ideas and to see the results of your trials.

F3. The software takes advantage of the power of a computer to do quite a bit of work for you. Both the storage and the processing power of the computer are used.

F4. The software is easy to learn how to use and easy to use. It is user friendly. You can easily learn how to use the software to help solve the kinds of problems that you are studying in school.

Many pieces of software have these features. In this chapter we will briefly discuss five of them. In each case we will look at examples of some of the kinds of problems that the software can help solve. Keep in mind that the computer is merely an aid to problem solving. You will need to do the underlying thinking!

A Review of Three Key Ideas in Computer Modeling

In the last chapter we talked about computer modeling. It is important that you understand some key computer modeling ideas. The computer tools we study in this chapter are actually general-purpose aids to doing computer modeling.

Computer modeling is a useful aid to problem solving because:

1. A computer can be used to model many different types of problems. A computer is a versatile tool, useful in modeling problems in every course that you take in school.
2. Computer models are easy to change. The computer may be able to do much of the work in making a change.
3. A computer can automatically follow a detailed set of directions. Once a computer model has been developed for a problem, a computer may be able to do much of the problem-solving work for you.

Word Processor

A word processor has all of the features F1 - F4 listed above. We assume that you have used a word processor, so we will not go into details on how to use one. Instead, we will look at some of the kinds of problems that a word processor can help solve.

1. **Organizing your thoughts.** You can use a word processor to outline a paper. You can rearrange the outline ideas until they seem right to you. You can then expand the outline into a complete paper. As new ideas occur to you, they can be inserted into the paper wherever they belong.
2. **Revision.** Good writers know that one key to good writing is, "Revise, revise, revise." A word processor is a very powerful aid to revision. This may be just making small changes, such as correcting a misspelled word. Or, it may be reorganizing entire sections and making major changes.

   It takes a lot of training and practice to get good at doing revision. Many students who have done all of their writing using pencil and paper are not good at doing revision They have not practiced it very much. One reason is that it is a lot of work to recopy pencil and paper writing.
3. **Mechanics.** There are many mechanical aspects of writing, such as correct spelling and grammar, readability, length, and so on. Computer programs have been written that can help find spelling and grammar errors. Computer programs can count the number of words in your writing. Computer programs can test readability level.
4. **Publication.** Probably you have heard of the idea of **desktop publication**. In recent years, better and better computer printers have been developed. Computer software has been developed to take advantage of these printers. Now many newspapers, magazines, and books are published directly from computer printouts. This is called desktop publication.

   It is easy to learn to do desktop publication. Many schools use desktop publication to do their school newspapers. Some use desktop publication to do their yearbooks.
5. **Making use of your previous writings.** With a word processor, you can save your writings on a computer disk. Days, weeks, or months later you may find that some of your old writings are useful in doing a new project. A computer makes it very easy to "cut and paste" pieces from old writings into new writings. It makes it easy to build on your previous writing work.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses that you are taking in school. For each course, think about how a word processor is useful. Order your courses on the basis of how useful a word processor is. The first course on your list should be the one in which a word processor is most useful.

Do you use a word processor in all of your courses? If the answer is no, discuss why not.

End ✍✍

Database

A **database** is an organized collection of data. If the data is stored in a computer, it is called a computer database. A computer database has all of the features F1 - F4 discussed earlier in this chapter.

There are many different kinds of databases that can be stored in a computer. Three types of databases are discussed below. Sometimes these different types overlap. That is, one database may contain features of two or more of the categories listed below.

1. Table database. The data is organized into rows and columns. Here is a small example.

Name	**Street Address**	**City**	**State**
Joan Adams	9884 Smith St.	New York	NY
Paul Jones	6824 South Plum St.	Columbus	OH
Tom Charles	2223 East Lake Road	Denver	CO
Sue Walden	221 Pine Blvd.	Houston	TX
Pat Smith	23232 Jackson St.	Los Angeles	CA

   Each row in the table is one record of information. Each record is divided into fields. The small table database given above consists of five records, and each record contains four fields. A large table database might contain many thousands of records and each record might contain dozens of fields.

2. Reference database. This is a database of references. It contains the author, title, publication data, a brief list of topics covered, and perhaps a brief summary. Here is one sample entry of a reference database.

   Citation: Moursund, David G. (1989). *Getting Smarter At Solving Problems*. International Society for Technology in Education, Eugene, Oregon.

   Descriptors: computer; computer applications; computer literacy; computer modeling; computer programming; higher-order thinking skills; journaling; metacognition; modeling; problem solving; thinking;

   Abstract: A secondary school book on roles of computers in problem solving. Covers basic ideas of problem solving in general and problem solving using computers.

Intended for use in a computer literacy course, but can also be used in other courses. No specific knowledge of computers or of mathematics is assumed. The problem solving ideas cut across all fields of study. The book stresses metacognition and having students do a lot of writing in a journal.

3. Full text database. As the capacity of computer storage devices have grown, it has become possible to store entire books (including pictures and diagrams) in a computer. Many schools now have an encyclopedia stored on a computer disk. Many reference databases contain the entire texts of articles.

One of the most important ideas in problem solving is building on the work that other people have done. But often it is quite difficult to gain access to this work. Even if they have written about their work and published articles on it, it is often hard to find the references.

Computer databases have made a big difference in helping people build on the work of others. Here are a few major idea of how computer databases help in problem solving.

1. **Sharing of current data.** There are many databases that need to be changed frequently. For example, consider the table database of seats on airplane flights. There are thousands of ticket agents who sell tickets. When a ticket is sold, the database needs to be changed.

   Similarly, consider a reference database. There are many thousands of magazine and journal articles published each week. Reference databases need to be updated frequently.

   Many grocery stores now keep their complete price lists in a computer database. This makes it easy to change prices. There is a computer terminal at the checkout counter. A bar code scanner reads the product number from a label on a grocery item. The computer then looks up the item in its database. It displays the item name and price on the checkout display and keeps a running total of the bill. This helps the store to do inventory control.

2. **Convenience of access.** Many computer databases can be accessed by use of a computer hooked to long distance phone lines. This means that the information comes to you, rather than you going to where the information is stored.

3. **Quick access.** Computer databases can be searched very quickly. The computer does most of the work for you.

4. **Reorganizing data.** A computer can be used to reorganize a computer database. For example, a table database can be ordered alphabetically based on the entries in a particular field. In the name and address table database given above, a computer could quickly put the records in ZIP code order.

5. **Low cost**. In many cases it is much cheaper to make use of a computer database than it would be to obtain the same information by non-computer means. For example, suppose that you are doing a school report and you need to read a particular article. Suppose that the article is not in your school library or any library in your town. If the article is in a full text computer database, you can quickly gain access to it. This may be

cheaper than your school subscribing to all of the magazines that students might need to read.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses that you are taking in school. For each course, think about how useful computer database might be. Order your courses on the basis of usefulness of computer databases. The first course on your list should be the one in which computer databases are most useful.

If computer databases are not used in your courses, think about why. How would computer databases change some of your courses?

End ✍✍

Graphics

Remember the quote, "A picture is worth a thousand words." It has long been recognized that pictures can be more effective than words in describing a scene. A picture is often a very good model.

Computers are very useful for storing and working with pictures, drawings, diagrams, and math graphs. **Computer graphics** have all of the features F1 - F4 discussed earlier in this chapter.

Here are three general types of computer graphic applications.

1. Math graphics. One example is the graphing of data, using a bar graph, circle graph, or line graph. Another example is the graphing of math equations.
2. Engineering graphics. This covers a wide range of areas, such as architectural drawings for a building and drawings of a part to be manufactured in a factory
3. Artistic graphics. This covers a wide variety of applications. Examples range from using a computer to produce nicely lettered signs to producing animated movies.

Computer graphics has opened up a whole new approach to problem solving. It is easy to use a computer to create pictures. The pictures may be in full color and they may even be motion pictures. (Take a look at the "credits" lines the next time you watch the evening news or go to a Star Trek movie.)

Computer graphics are particular useful in problems with the following characteristics.

1. **Changeability.** Imagine that you are designing a cover page for a report. The cover page will contain pictures and lettering. This is easy to do on a computer, but hard to do by hand. When you are doing it on a computer, it is very easy to correct mistakes. You can look at what you have produced, and decide if you like it. If you don't like some parts, it is easy to change them.
2. **Pictorial representations of data.** The human mind is not good at dealing with a large table of data. For example, think about a table of data giving the population density for each state in the country. It would be hard to see patterns and to answer questions about where there are high or low densities of population. But a computer

could easily represent this data as a map of the country. It could use different colors to represent different population densities. Then you could tell at a glance the regions of high or low population density.

3. **Color and motion.** The computer is beginning to take on some of the features of a video camera. You can use a computer to do animation. Video pictures and sound tracks can be stored in a computer system. These can be combined with your drawings and writing. The result is called **hypertext**. It is a new form of "writing" that did not exist before computers.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses that you are taking in school. For each course, think about how computer graphics could be useful. Order your courses on the basis of usefulness of computer graphics. The first course on your list should be the one in which computer graphics is most useful.

If computer graphics are not used in your courses, discuss why. How would your courses be better if computer graphics were used.

End ✍✍

Spreadsheet

Perhaps you have seen the type of paper that accountants use to keep detailed business records. The paper is ruled into rows and columns to make a large number of little boxes, or "cells." Each cell can hold a number, a few words, or a formula.

A spreadsheet is merely a computerized accounting sheet. A spreadsheet has all of the features F1 - F4 discussed earlier in this chapter. You can enter words and numbers into the cells on the page. In addition, you can write formulas that tell a computer what to do with the numbers.

For example, look at the little piece of a grade book given below. It is a spreadsheet model (a computer model) of a gradebook. The teacher has given three assignments and one quiz. The teacher enters the student names and scores into the spreadsheet. The spreadsheet calculates the student total scores as well as the averages. It does this by using simple formulas that the teacher has given to the spreadsheet program.

Suppose that the teacher finds an error in a student's score. It is easy to correct the error. The teacher types in the correct number. The computer does all of the rest of the work. It recalculates all of the totals and averages.

Student Name	Assign. # 1	Assign. # 2	Assign. #3	Quiz # 1	Total
	(10 possible)	(5 possible)	(10 possible)	(30 possible)	
Adams, Ruth	8	4	9	22	43
Best, Bob	5	5	10	19	39
Dowden, Terry	10	3	10	28	51
Gold, Sam	9	5	8	26	48
Lansing, Paul	9	5	7	20	41
Perez, Pat	10	4	9	25	48
Average	8.50	4.33	8.83	23.33	45.00

A spreadsheet is useful whenever one is working with table of numbers that are to be connected by formulas. This is common in business, and it often occurs in science, math, and social studies. Thus, a spreadsheet is a rather general-purpose aid to problem solving. It can be used to model many different kinds of problems.

It is easy to learn how to do a few simple things with a spreadsheet. However, a spreadsheet is a very complex tool. Many high schools and colleges offer entire courses on how to use a spreadsheet.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses that you are taking in school. For each course, think about how a spreadsheet might be useful. Order your courses on the basis of how useful a spreadsheet might be. The first course on your list should be the one in which a spreadsheet is most useful.

If spreadsheets are not used in your courses, discuss why. How might your courses be better if they helped you to learn to develop and use spreadsheet models.

End ✍✍

Networking Computers

This section discusses the idea of connecting computers together. If the computers are located close together, this can be done by direct wiring. If the computers are a long distance apart, they may be connected together through use of the telephone system. The computers that are connected together are called a **computer network** or a **network**.

People using computer network can communicate with each other or with information stored on each machine. There are three major types of network use.

1. Communication among people. This can occur in several forms. In **electronic mail (E-mail)** one computer user sends a message to another computer user. The message is private, and other people using the computer network are not allowed to read the message.

In an electronic bulletin board, messages are "posted" so that all users of the system can read them. It is just like a school bulletin board, but only users of the computer system can read the messages.

2. Accessing databases. This idea was discussed earlier in this chapter.
3. Sharing computer resources. A computer network might have just one printer or perhaps just one hard disk. All users of the network can make use of the printer or hard disk. In another type of application, there may be a centrally located very powerful super computer. Users of the system can have the centrally located computer carry out massive computations that would take far too long on their own local computers.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses that you are taking in school. For each course, think about how computer networking would be useful. Order your courses on the basis of how useful computer networking would be. The first course on your list should be the one in which a computer networking is most useful.

If computer networks are not used in your courses, discuss why. How would your courses be better if you were using networking in them?

End ✍✍

CHAPTER 9 SUMMARY

Some computer software is designed to help solve a wide range of problems. This software can be used to build computer models for a wide range of problems.

Key features of general-purpose software include:

F1. The software is useful in helping to solve many different kinds of problems from many different fields.

F2. The software is useful in working on the kinds of problems in which one needs to make many changes.

F3. The software takes advantage of the storage and processing power of a computer to do quite a bit of work for you.

F4. The software is easy to learn how to use.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how some piece of computer software helped you to solve a problem. Perhaps you thought about some general-purpose computer software that was not discussed in

this chapter. Perhaps you thought about how it would be fun to use some of the general-purpose pieces of software in other classes that you are taking. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 9 ACTIVITY 1

   AN IDEA I HAD WHILE I WAS READING CHAPTER 9

2. Write down and explain the idea.
3. Explain why the idea interests you. Why did you remember this idea?
4. How does this idea relate to things that you do outside of this class?
5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

   computer network (network)

   database

   desktop publication

   electronic mail (E-mail)

   graphics (computer graphics)

   human-machine interface

   hypertext

   spreadsheet

   user friendly

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions

that can be answered by a person who has a good understanding of the material and ideas in this chapter.

Then try out your quiz on two students in your class.

5. Think about using a word processor to do a hard multiplication or division problem. (This is like doing arithmetic on a typewriter.) For example, think about using it to do 973 x 729 or perhaps 683073 ÷ 729. Then actually try doing these computations using a word processor. Write a brief discussion of your conclusions.
6. Select a general-purpose software tool that you have not used before. Learn to use it. As you are learning, think about how you are learning. Keep detailed notes in your journal. Write about "learning to learn."
7. Some of the basics of education are reading, writing, arithmetic, speaking, and listening. The most widely used general-purpose computer application packages are database, graphics, networking, spreadsheet, and word processing. Compare and contrast these two lists. How are they the same, and how are they different? Use this comparison to predict some new general-purpose computer applications that may be developed in the future.
8. Many science fiction stories talk about a "voice writer." It is a typewriter that you can talk to. Suppose that young children had a voice writer as they were learning to write. How do you think this would change learning to write?

Chapter 10

Computer Systems

ORGANIZE YOUR THINKING
A computer system consists of hardware and software. Hardware is physical machinery. Software is computer programs. The computer field is changing quite rapidly. Each year, computer systems improve quite a bit. Both the hardware and the software get better. To use a computer, you must communicate with the machine. You must tell it what to do. Modern computers are much easier to use than older computers because it is easier to tell them what to do. Rapid progress is continuing in this area.

Introduction

Some people think of a computer as a mysterious "black box." With this approach, you do not need to know what goes on inside the black box. You tell it to do things, and it does them. You need have little understanding of how the machine actually works.

However, most people like to have an understanding of what goes on inside the machines they use. It is fun to understand the internal workings of machines. Also, it will help you to make better use of the machine. This chapter will increase your understanding of how a computer actually works.

Begin ✍✍ (You may want to write in your journal.)

Are the internal workings of a car a "black box" for you? How about an electric motor? A light bulb? Think about the idea of a black box. How does it feel to use devices that you do not understand?

End ✍✍

What Can A Computer Do?

A **computer system** consists of **hardware** (physical machinery) and **software** (computer programs). Basically, a computer is a rather simple machine. It can only

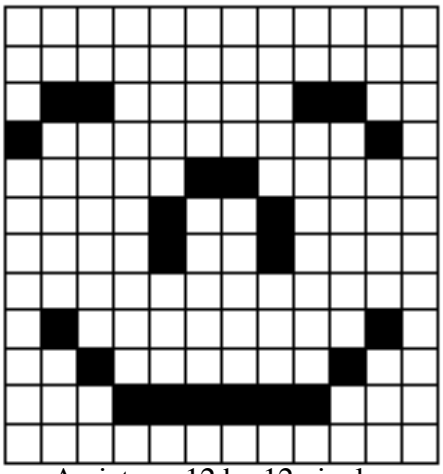
do very simple things. However, it does these simple things rapidly and accurately. Here are the main things a computer can do.

1. A computer can work with letters, digits, punctuation marks, and other symbols.

   A keyboard containing these symbols is used to "talk to" a computer. You know how to read and write using the same symbols that computers use. This helps you in learning to use a computer.

2. A computer can work with pictures and sound.

   Think of a picture as being made up of small dots or small squares. These are called **pixels** (picture elements). A computer can store a picture as a set of numbers. Each number gives the color of one pixel in the picture.



A picture, 12 by 12 pixels.

   One way to store sound in a computer is to break it into many short segments. Measure the frequency of each segment. Store the numbers that represent these frequencies. This same idea is used to store music on compact discs.

3. A computer can do some simple operations such as adding two numbers and comparing two numbers to see which is larger.

   Every computer contains at least one **central processing unit** (CPU) The CPU carries out simple tasks such as adding a pair of numbers or checking to see if a number is negative.

4. A computer memory can store a computer program–a detailed step by step set of directions. A program tells a computer's CPU what to do to solve some problem.

   The key idea is that a computer memory can store both the data you want to process and the program telling how to process the data. Both the data and the program can easily be changed to help solve different problems.

5. A computer can carry out the steps in a computer program very rapidly and very accurately.

   A modern computer can carry out millions of individual operations in one second. It can function for many days without making a single mistake.

Hardware: A Very Brief History

The history of computer hardware is a history of change. Until about 50 years ago, the rate of change was slow. The first general purpose electronic digital computer was completed in 1945. Since then, change has been rapid. One reason for studying the history of computer hardware is to understand how this rapid rate of change affects you.

The history of computer hardware is a story of people seeking ways to make it easier to do arithmetic. The abacus, invented about 5,000 years ago, can be thought of as a distant relative of the modern computer. It many countries it is still used today.

More than 300 years ago people began to build mechanical calculators that could add, subtract, multiply, and divide. The arithmetic was done by a collection of gears.

During the 1800s, people got the idea of building calculators that could automatically follow a sequence of instructions. However, such machines proved to be very difficult to build. Herman Babbage and Ada Lovelace are remembered for their work on these early computer systems.

During the 1930s, people got the idea of using electrical and electronic parts to build automatic calculating machines. This eventually led to the development of the electronic digital computer. During the early 1940s, rapid progress in building such computers occurred in Germany, Great Britain, and the United States.

After these first computers were developed, people realized they could be used to do more than just simple arithmetic. Computers could work with words and pictures. Computers could carry out tasks that previously had seemed to require human intelligence. The field of computer science was born!

During the 1950s, the computer industry developed. Many different companies built and sold computers. Computers began to become common in business, government, and in higher education.

But all of the early computers used vacuum tubes. A vacuum tube uses a lot of electrical power. These tubes produce quite a bit of heat. Also, vacuum tubes are somewhat like electrical light bulbs—they burn out frequently. The early computers contained many thousands of vacuum tubes. They required lots of electrical power and very good air conditioning. They were not very reliable because tubes burnt out so often.

The invention of the transistor changed all of this. A transistor can do the same things as a vacuum tube. It is much smaller than a vacuum tube and it doesn't burn out as fast. It uses very little electrical power. The first computers that used transistors were built in the late 1950s.

Transistor technology has progressed at a very rapid pace. People discovered how to build an **integrated circuit** that contains a large number of transistors and other electronic parts. An integrated circuit is sometimes called a **chip** because a

small piece of silicone (a "chip" of silicone) is used in the manufacturing process. A chip is about the size of your fingernail.

Now a single integrated circuit may be equivalent to a million vacuum tubes. This progress has made it possible to have very cheap hand held calculators, portable computers, and computers in schools. Computers are cheap enough so that millions of people have them in their homes.

Roughly speaking, computer hardware has made progress by a factor of one million during the past 40 years. This means, for example, that the cost of a given amount of computation has decreased by a factor of about a million during that time. Hardware will continue to improve very rapidly for the next few decades.

This progress will affect you. Twenty years from now people will look back at the computers now being used in schools. They will laugh at these primitive "toys." However, the basic ideas on using a computer to help solve problems will not have changed very much. If you learn how to use computers to solve problems, the underlying ideas will last a lifetime!

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   RAPID CHANGE

2. Make a list of some things that seem to change very rapidly. Your list might include "popular" television programs, your younger brother or sister, medicine, and consumer products.
3. For each item on your list, briefly discuss how the changes affect your life.

End ✍✍

Computer Software

A computer program is a set of directions telling a computer what to do. If the task is quite simple, then the computer program may be quite simple. However, if the task is complex, the computer program may be very complex. Some computer programs contain millions of instructions. Teams of programmers may work for years on some programming projects.

Let's try a little experiment. Pick up a pen or pencil. Draw a small circle. Then draw a smaller circle inside of the circle. Put down the pen or pencil.

You have just carried out a step-by-step set of directions. Unless you have a disability that makes the operations difficult or impossible, it was easy for you to understand and follow the directions.

However, when you were very young, you couldn't have followed this set of directions. It took you a long time to train your body to be able to do things like pick up a pencil or draw a circle. These are actually quite complex operations. Your

mind and body can do them automatically now only because you learned through a great deal of practice.

Now think about picking up your pencil, going to the pencil sharpener, sharpening your pencil, and returning to your seat. Please do the following writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   TO SHARPEN A PENCIL

2. Write a detailed step by step set of directions for the process of going to the pencil sharpener and sharpening your pencil.
3. Then examine each of the steps to see how hard it is to do. List the two easiest steps and say why they are easy. List the two hardest steps and say why they are hard.
4. Did your set of directions take into consideration that the lead might break while you are sharpening your pencil? If not, add this to your directions.

End ✍✍

Programming Languages

A set of directions tells **somebody** or some **thing** what to do. A set of directions must take into consideration the capabilities of the agent that will carry out the directions. If the agent is very "smart," the directions can be quite simple. For example, you can say, "Walk to the pencil sharpener." to a person. The person will avoid stepping on people and walking over desks and chairs.

You can think of a robot as a computer with a television camera for an eye and with mechanical arms and legs. How do you tell a robot to sharpen a pencil? How can the robot tell when it is sharp? How do you tell a robot to not step on people? These are very hard questions. Programmers who work with robots have a hard time figuring out answers to these kinds of questions.

A computer is designed to be able to carry out certain types of instructions. You can think of each of these as a primitive, a very simple problem that the computer can solve. A computer only "understands" a language consisting of these primitives. This is called a **machine language**. A machine language program is a set of instructions telling a computer which primitive operations to perform.

Computers are not all alike. Different brands or different models of computers may have different sets of primitives built into them. That is, they have different machine languages. A computer program written in the machine language of one machine may not be useable on a different machine.

Another difficulty is that the machine language steps that a computer can carry out are very simple relative to the tasks that people want accomplished. Think about

how many different steps it takes to look up a word in a dictionary. A machine language program to do this is a large list of instructions. The smallest error in this set of instructions will lead to the computer making errors.

Most people are not good at writing detailed instructions that contain no errors (**bugs**). It is difficult to write error-free (bug-free) programs. It also difficult to detect and correct errors in a computer program (**debug** a program)**.** A computer programmer must be skilled at detecting and correcting bugs.

Thus, early computer scientists put a lot of thought into how to help people write computer programs. They developed the idea of a programming language that was more like human "natural" language than a machine language. The idea was to develop a language so that a computer could translate from it into machine language. This is called a **higher level programming languages**

One of the very early higher level programming languages was called Fortran. It was completed in 1957 and was designed to be used by scientists and engineers. It is still widely used. One reason for this is that billions of dollars have been spent in writing Fortran programs. These programs are still useful. They are a way that people build on previous work of other people.

In the 1960s, a higher level programming language called BASIC was developed to be used by college students. It is now widely used by younger students and by many other people.

Many other languages were developed to meet the needs of different people. For example, COBOL was designed for use in business. It is still widely used because many billions of dollars have been spent writing COBOL programs.

Logo was designed to fit the needs of elementary school students. It is now used at all grade levels and even in some colleges.

Begin ✍✍ (You may want to write in your journal.)

A computer program can translate a BASIC program or a Logo program into machine language. Can a computer program translate Russian into English? In what sense are these translation problems alike? How are they different?

End ✍✍

Sample Computer Programs

Here are a couple of very simple programs written in BASIC. The first directs the computer to ask the name of the person using the program. The computer then prints out the word HELLO followed by the name. The second asks the user to type in two numbers. The computer then finds the sum of the two numbers and prints it out.

Each line of a BASIC program has a line number. These simple programs have line numbers incremented in steps of 10. This makes it easy to insert additional instructions between the current lines of the programs.

```
10 PRINT "WHAT IS YOUR NAME?"
```

```
20 INPUT N$
30 PRINT "HELLO "; N$
40 END
```

```
10 PRINT "THIS PROGRAM ADDS TWO NUMBERS."
20 PRINT "PLEASE TYPE IN THE FIRST NUMBER."
30 INPUT A
40 PRINT "PLEASE TYPE IN THE SECOND NUMBER."
50 INPUT B
60 LET C = A + B
70 PRINT "THE SUM OF THE TWO NUMBERS IS "; C
80 END
```

Here is a simple Logo program. It directs the computer to draw a simple picture. The picture is a "house" made up of a triangle sitting on top of a square.

```
TO HOUSE
SQUARE 50
MOVE.TO.ROOF 50
TRIANGLE 50
MOVE.TO.START 50
END
TO SQUARE :SIZE
REPEAT 4 [FORWARD :SIZE RIGHT 90]
END
TO TRIANGLE :SIZE
REPEAT 3[FORWARD :SIZE RIGHT 120]
END
TO MOVE.TO.ROOF :LENGTH
FORWARD :LENGTH
RIGHT 30
END
TO MOVE.TO.START :DISTANCE
LEFT 30
BACK :DISTANCE
END
```

Hundreds of higher level programming languages have been developed. All have certain features in common:

1. Each was designed to fit the needs of certain types of programmers. A language for solving business problems may not be very good for solving science problems. A language for grade school students may not be good for college students.

2. Each can be used on a variety of makes and models of computers. When a new type of computer is produced, people write a translating programs for each language that is to be used on the new computer.

   For example, suppose that a manufacturer wants a new computer to use BASIC, COBOL, and Logo. Then three translating programs need to be written. One must translate BASIC statements into the machine language of the new computer. The second must translate COBOL statements and the third must translate Logo statements.

Making Computers Easier to Use

Higher level programming languages make it easier for people to write programs. The computer can do quite a bit of the work. This is an interesting idea. Are there other ways that a computer can help a person to use a computer?

The answer is "yes." Many researchers work on making computers easier to use. They have made a great deal of progress. At one time it was thought that most people needed to learn how to write computer programs if they wanted to use computers. Now this is definitely incorrect! Most people who use computers know little about computer programming.

Instead, most computer users make use of application packages. These are designed to be easy to learn how to use. A modern word processing program is a very sophisticated piece of software. The program may be tens of thousands of lines long. However, it takes only a few minutes to learn to do some very useful things with a word processor.

Similar statements hold for applications such as spreadsheet, graphics, and database. Each of these application packages is a complicated computer program. But, many of these application packages are easy to learn to use. Typically, each major application package is designed for working on only certain types of problems. You wouldn't want to use a word processor to try to solve spreadsheet or database problems!

Also, the ease of use in solving simple problems is misleading. For example, the instruction manual for the word processor may be hundreds of pages long. It takes hundreds of hours of study and practice to master all of the features of a modern word processor. Similar statements hold for the other major computer applications.

There is still one more level of complexity. A modern application package may contain a built-in programming language. A database system provides an excellent example. A modern database application package includes a programming language designed to help solve database problems. You can easily learn to use the database software at a simple level to solve simple problems. This may take only a few hours of effort. However, it may take hundreds of hours of study and practice to fully master such a piece of software.

Some Thoughts on Being a Computer Programmer

Every student can learn to write simple computer programs to solve simple problems. Millions of grade school students have learned to write simple programs in Logo. Millions of secondary school students have learned to write simple programs in BASIC or Logo. Nowadays, almost all college students in science and engineering learn to write computer programs. They write programs to solve the kinds of problems that come up in the courses they are taking.

However, application packages are getting better and better. More of these packages are being developed. This means that for any particular area of study, there is probably software that is designed just for people in this field. At a beginner's level, the software is almost always easier to learn to use than is a general purpose programming language. You can quickly learn to use the application package to solve a variety of simple problems.

However, as you attempt to solve more difficult problems you will find that it takes a great deal of study and practice. The task is much like learning a general-purpose higher level programming language.

This leads to two questions. Who should learn to write computer programs? Who should seek a career as a computer programmer? The following ideas may help you answer these questions for yourself.

1. You can learn to write simple programs in a language such as BASIC or Logo. This can be a very useful part of your education. The goal isn't really to learn the programming language. Rather, the goal is to learn about learning a programming language. Learn what is involved in solving problems by writing programs. You want to learn how your mind works as it deals with these tasks.
2. In may fields, such as business, engineering, and science, it is very useful to be able to write programs. If you intend to go to college and major in one of these areas, you will likely benefit by learning to write computer programs.
3. A professional computer programmer is a person who has a combination of skills that include:
    A. The ability to master several general purpose programming languages as well as several modern application packages.
    B. The ability to write programs that help to solve the types of problems in a particular area. A programmer gets hired to help solve certain types of problems, such as business problems or science problems. To solve the problems in a particular area, you need to know a lot about the area and be good at solving problems.
    C. Good skills in communicating with the people who need to have programs written. Generally, this means that you need to have good oral and written communication skills.

D. The ability to rapidly learn about new computer hardware and new computer software. The computer field will continue to change very rapidly for many years to come.

E. Good problem-solving skills. Patience and persistence. The willingness to work quite hard.

A computer is an aid to problem solving. A computer programmer tells a computer how to solve problems. Computer programming requires a precision of communication. A computer does exactly what it is told to do. The smallest error on the part of the programmer can lead to a computer producing wrong answers to a problem.

Some people enjoy working in a area that requires very precise thinking and very precise communication. Other people do not like this environment. One reason for learning some computer programming is to learn more about yourself. Learning more about yourself is certainly one of the ultimate goals in education.

CHAPTER 10 SUMMARY

Each year sees continued rapid progress in computer hardware and software. This progress is occurring in three areas:

1. Developing hardware that is faster, more reliable, and cheaper.

2. Developing software that is easier to learn how to use and easier to use.

3. Developing packages of applications software that can solve or help solve the problems in a particular discipline.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how your mind is like a computer and how school is "programming" your mind. Perhaps you thought about how some subjects seem to contain many detailed step by step sets of directions that you have to learn, and others contain very few. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

   _____

   CHAPTER 10 ACTIVITY 1

   AN IDEA I HAD WHILE I WAS READING CHAPTER 10

   2. Write down and explain the idea.
   3. Explain why the idea interests you. Why did you remember this idea?
   4. How does this idea relate to things that you do outside of this class?
   5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea that seems particularly important to you from this chapter. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you.? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

   bug

   central processing unit (CPU)

   chip

   computer system

   debug

   hardware

   higher level programming language

   integrated circuit

   machine language

   software

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. In what ways is communicating with a computer like talking with a person? In what ways is it different? Do you think that a person with good skills in talking with other people will be a good computer programmer? Why?
6. Do you know how to write computer programs? If 'yes,' do some metacognition on the learning process. Do you enjoy writing programs? Was it hard to learn? Would you like to learn more about programming?
7. Write arguments for both sides of the question, "Should all students learn how to write computer programs?" Then summarize by giving your personal opinion.
8. This book raises the question, "If a computer can solve or help solve a type of problem that students study in school, what should students learn about solving this type of problem." Write an essay on this question.
9. What do you feel are the most important ideas in this book? Why?

Glossary

One of the major goals of this book is to help you gain vocabulary that allows you to talk and write about problem solving. Being able to talk and write about a problem is a big help in working to solve the problem. Thus, you should place considerable emphasis on learning to talk and write using the terms contained in the Glossary.

The number is parenthesis after a term is the chapter in which the term is first defined. In some cases, a term is used earlier in the book without being define. In a few other cases, a term is used without being defined.

Advance organizer (1): A brief introduction to a lesson or a chapter. It contains a few of the key ideas that will be covered in the material. Its purpose is to get your mind started thinking on the new ideas.

Algorithm: A step by step set of directions that tells how to solve a particular kind of problem. It is guaranteed to solve the problem provided no errors occur in following the directions. Math courses often talk about algorithms for multiplication, division, calculating square root, and solving other computational problems.

Basic skills (1): Skills that can be used to help understand and solve a wide range of problems. Educators suggest that reading, writing, arithmetic, speaking, and listening are basic skills. They want all students to gain these skills.

Brain: Your brain contains many billions of neurons. The neurons store information and process information. Each neuron is somewhat like a computer CPU with some attached memory.

Bottom-up strategy (5)**:** A strategy for problem solving that involves starting with primitives. The strategy may be goal directed, so primitives are put together with a specific goal in mind. But the strategy may also be used in a rather random and creative fashion, with no particular goal in mind. A goal may later be selected based on observing the outcome of carrying out some primitives.

Bug (10)**:** An error or a mistake. A software bug may be an error in the design of a plan on how to solve a problem. It may be an mistake in details of the implementation of a procedure to carry out a plan. A hardware bug refers to circuitry that is not working right.

Calculator primitive (5): A primitive you have because the solution process is built into a calculator and you have access to the calculator.

Central Processing Unit (**CPU**) (10) The part of computer circuitry that actually carries out the instructions given in a computer program. Some computers contain only one CPU. Others contain a large number of CPUs and many of them may be engaged

simultaneously working on a single problem. This parallel processing is somewhat akin to how the neurons in a human brain function.

Chip (10): See **integrated circuit**.

Clearly-defined problem (3)**:** A problem in which the Givens, Goal, and Resources and Restrictions are all clearly specified.

Cognition: Thinking

Computer graphics (9): Use of a computer to store, manipulate, and display pictures, diagrams, and other graphic images.

Computer model (8): A model for a problem that is stored in a computer in a form so that the computer can carry out computations and other activities needed to make use of the model. A computer can store letters, digits, punctuation marks, and other symbols using a binary code. It can also store pictures in a binary-coded form.

Computer network (9): A collection of computers and other computer facilities connected together to allow electronic communication among them.

Computer primitive (5): A primitive that you have because you have a computer program that can carry out the process of solving a particular problem as well as access to a computer that can run the program.

Computer program (3): See **software**.

Computer symbolic model (8): See **computer model**.

Computer system (10): A combination of computer hardware and software that works together. See **hardware** and **software**.

Conscious short term memory: See **short term memory**.

Constructivism: A view of learning in which knowledge is something that the individual learner must construct for and by themselves.

Cooperative learning (3)**:** An approach to learning in which small groups (usually 3-4) of students work together. Students help each other to learn. They have both shared and individual responsibility for learning.

CPU: See **central processing unit**.

Database (9): An organized collection of data. A computer is very useful for storing and retrieving databases. A computer is also very useful in manipulating the data in a database to help solve a problem.

Debug (10): To remove bugs from your overall process for solving a problem

Desktop publishing (9): The use of a computer system for word processing, page layout, and printing in the overall process of publishing.

Domain specific knowledge: The detailed knowledge of a particular field of study. Each field of study has accumulated a great deal of knowledge. One can think of a field of study as being defined by the types of problems that it works to solve, the techniques that it has developed, its vocabulary and notations, and so on. Research suggests that it

is necessary to have considerable domain specific knowledge in order to solve the problems in a domain.

Electronic mail; E-mail (9): Mail messages sent via computer network.

Far transfer situation (7)**:** When two problem situations seem so different to you that you do not readily transfer the knowledge and skills that will help deal with one of the problem situations to dealing with the other problem situation.

Formal problem: Vocabulary used to emphasize that the problem has the four components Given Initial Situation, Goal, Resources, Ownership. Careful attention has been paid to ensuring all are present and clearly defined.

Four-step plan for solving a problem (4): See **four-step strategy for solving a problem.**

Four-step strategy for solving a problem (4): A strategy consisting of the four steps:

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan of action.
4. Exam the results for correctness and for whether a new problem has been created.

Givens; given situation (3)**:** See **given initial situation**.

Given initial situation (3)**:** One of the four components of a problem. It is the initial state, the way things are to begin with.

Goal (3)**:** One of the four components of a problem. It is the desired final state, the target, what one would like to reach.

Graphics (9): See **computer graphics**.

Hardware (10): The physical machinery of a computer system. It includes components such as printer, disk drive, display screen, keyboard, memory, and central processing unit.

Heuristic: A rule of thumb for solving a specified type of problem. A step by step set of directions that is not guaranteed to work but which seems applicable and has been designed to have a reasonable chance of working. .You can think of a heuristic as an algorithm that is not guaranteed to work.

Higher level programming language (10)**:** A programming language such as BASIC, COBOL, or Logo in which each statement gets translated by the computer into a number of machine language statements.

Higher-order thinking skill (1)**:** The human brain can deal both with simple facts and with complex ideas and relationships. Higher-order thinking skills deal with complex ideas and relationships. Why do we say that Columbus discovered America when there were already people living there when he arrived? What makes a president or a prime minister a good leader? Why do some people live in poverty and what can we do about it?

Human-machine interface (9): The hardware and software system that people use to communicate with a computer and that a computer uses to communicate with a person. When this system is designed so that it is easy to use, it is called **user friendly**.

Hypertext (9): A computer-based "text" that may include writing, pictures and drawings, and sound. It may include still and motion pictures that are stored in a videotape or videodisc system. Generally the text is not organized in a linear fashion like a book. Thus, it can only be conveniently stored and read by making use of a computer.

Information Age (1)**:** A society in which more people work in information-related and service jobs than work in industrial manufacturing or agricultural types of jobs. In the United States the Information Age began in 1956. At that time the number of people working in service jobs and information processing jobs first exceeded the number working in industrial manufacturing jobs.

Integrated circuit (10): A thumbnail-sized circuit containing a large number of transistors and other electronic components. It is often called a chip because of the small piece (chip) of silicone used in its manufacture.

Learning theory (7): A theory about how the brain works when it is learning new things.

Long term memory: The permanent, or very long term, storage part of your brain.

Lower-order thinking skills (1)**:** The human brain can deal both with simple facts and with complex ideas and relationships. Lower order thinking skills deal with simple facts that can be memorized and recalled. What is the name of the small four-footed furry animal that says meow? What does a refrigerator do? What is the Information Age? See also **higher-order thinking skills**.

Machine language (10)**:** Each computer is designed to "understand"—that is, be able to carry out—a limited number of different types of operations. These operations, or primitives, are called the machine's language. Different brands or models of computers may have different machine languages.

Mathematical model (8)**:** The representation of a formal problem using the vocabulary and notation of mathematics. A formula such as A = L x W is a mathematical model.

Metacognition (2)**:** Thinking about thinking.

Mental model (8)**:** A model formed in one's head. The representation of a problem via mental imagery.

Model; modeling (8)**:** A model is an abstract representation of something. It represents certain key characteristics well enough so that information gleamed from working with the model is likely to be applicable to the real thing. See also **computer model**, **mental model**, **symbolic model**, and **verbal model**.

Near transfer situation (7)**:** When two problem situations seem quite alike to you. Then you can easily and readily transfer knowledge of how to deal with one of the problem situations to dealing with the other problem situation.

Network (9): See **computer network**.

Ownership (3)**:** One of the four components of a problem. A problem can only exist if a person or group of people are interested in it, involved with it, willing to devote time and energies to moving the Given Initial Situation into the Goal Situation.

Parallel processing: An advanced compute processing technique that allows the computer to perform multiple processes at the same time, "in parallel." The human brain naturally functions in this manner, since every neuron has both storage and processing capabilities.

Pixel (10): Picture element. Think of a computer display screen as being divided into a large number of small dots or elements. A computer can store a picture by storing information about the color of each each element (each pixel) that make up the picture.

Poorly-defined problem (3)**:** A problem situation in which one or more of the defining components Givens, Goal, and Resources and Restrictions are not clearly defined.

Primitive (5)**:** A problem that you can solve easily, quickly, and accurately. A "building block" problem that you can use in the process of solving more complex problems. See also **top-down strategy** and **bottom-up strategy**.

Problem (3)**:** A problem consists of four components: Given Initial Situation, Goal, Resources and Restrictions, and Ownership. Many people who define the term problem also require that the person who has the problem not be aware of any immediate and obvious procedure for solving it. This approach, unfortunately, leads to the situation that if one studies and works on a problem sufficiently, it may no longer be a problem.

Problem posing (3)**:** The process of creating a clearly-defined problem. One may pose a problem for them self or for others.

Problem situation (3)**:** A situation which concerns or disturbs you. A dissonance. A situation in which you are aware of a difference between the way things are and the way you would like them to be. A problem-like situation lacking one or more of the four components of a clearly-defined problem.

Procedure: A detailed step by step set of directions that can be carried out by a computer. (Or, it can be a set of directions that can be carried out in a non-thinking manner by some other machine or person.) Note that a procedure need not have been proven to work or to always work; a buggy program is still a procedure. See also **algorithm** and **heuristic**.

Program: When talking about computers, the word 'program' is usually taken as short for computer program or to indicate the process of writing a computer program. See **software**.

Resources and restrictions (3)**:** One of the four defining components of a problem. The types of allowable activities that a person is allowed to use in working to move from the Givens toward the Goal in working to solve a problem.

Scale model (8)**:** A physical model of an object, constructed to a scale such as one inch in the model corresponds to one foot in the object.

Short term memory: The temporary storage, active memory part of a brain. The "conscious" short term memory of most people can only store a few chunks of information.

Smart person.(2): You are a smart person if you can understand and can solve the problems that you encounter. The more of these problems you can solve, the smarter you are. A smart person can solve lots of different kinds of problems. A smart person can solve hard problems and can learn to solve new problems.

Software (10): A detailed step by step set of directions that can be stored in a computer memory and that a computer can automatically follow. Applications software consists of programs such as a word processor or a database that are designed to help solve rather specific problems. Systems software includes general purpose programming languages such as BASIC, Logo, and Pascal.

Spreadsheet (9): A computer program that models and helps automate many of the key features of an accounting worksheet.

Strategy (1)**:** An overall or general plan of action for attempting to accomplish some type of task or solve some type of problem. There is no guarantee that the plan will work. There are lots of different strategies that can be used in trying to solve a problem.

Symbolic model (8)**:** A model making use of symbols, such as letters, digits, diagrams, and other symbols. See **computer model** and **written model.**

Top-down strategy (5)**:** A strategy of breaking a problem into smaller problems. The goal is to arrive at primitives. When all of the primitives are solved and the results are combined in an appropriate manner, the original problem is solved.

Unsolvable problem (4): A clearly defined problem that cannot be solved. Quit a bit of work in higher math focuses on proving that certain kinds of math problems cannot be solved. In physics, the Heisenberg uncertainty principle is a statement that the problem of specifying the position and momentum of a particle cannot be measured simultaneously with arbitrarily high accuracy.

User friendly (9): The description of a human-machine interface that is easy to use and easy to learn how to use. More generally, a computer system is said to be user friendly if it is easy to use, forgiving of minor errors, and easy to learn how to use.

Verbal model (8)**:** A model formed from spoken words and other sounds.

Verbal/body language model (8)**:** A model represented by spoken sounds and body language. See **verbal model.** Often the term verbal model is intended to include body language.

Word processor: A computer program designed to assist in writing. It can be thought of as an electronic typewriter with memory and some other computer-like features.

Written model (8): A model formed by using written letters, digits, punctuation marks, diagrams, and other written symbols.

Written symbolic model (8): See **written model.**