

# Teacher's Guide to Computers in the Elementary School

**David Moursund**

Dept. of Computer & Information Science

University of Oregon

Eugene, Oregon 97403

Copyright © ICCE 1980. Copyright © 2005 David Moursund

<http://darkwing.uoregon.edu/~moursund/dave/index.htm>

## Contents

Preface to the 2005 Reprint.....	2
Preface to the 1980 Edition.....	5
Introduction.....	6
What is a Computer?.....	10
What is Interactive Computing?.....	12
What is Computer Hardware?.....	14
What is Computer Software?.....	16
What are Programming Languages?.....	18
Main Categories of Educational Use of Computers?.....	21
What Impact Should Computers Be Having?.....	23
How Are Computers Used as an Aid to Instruction?.....	26
What Should Elementary School Students Learn?.....	29
What Role Should Calculators Play?.....	32
What do Elementary School Teachers Need to Know?.....	35
Elementary School Computer-Related Activities.....	37
The Psychological Barrier.....	38
Computer Related Activities.....	39
Calculator-Based Activities.....	41
Computer Activities.....	42
Brief Guide to Periodical Literature.....	44
Glossary.....	46

## Preface to the 2005 Reprint

The first and second books book published by the International Council for Computers in Education were:

Moursund, David (1980) *School Administrator's Introduction to Instructional Use of Computers*. Eugene, OR: ICCE. Access at <http://darkwing.uoregon.edu/~moursund/dave/SchoolAdministrator.html>.

Moursund, David (1980). *Teacher's Guide to Computers in the Elementary School*. OR: ICCE.

The two books overlap considerable in content. Both were 48 page "booklets" and both sold for \$2.50 for a single copy. Both were based on a question and answer format, and both were illustrated by Percy Franklin. The intent in both cases was to keep the books rather easy to read and non-threatening to the reader. Both sold rather well, as there was little competition at that time.

These two books were written nearly 25 years ago. I find it very interesting to reflect on the changes that have occurred in Information and Communication Technology (ICT) in education during this time period. As I was reading this 1980 booklet for elementary school teachers, I found that I was disappointed in the progress we have made.

It is easy to point the "blame" finger at all kinds of people and organizations. But, here I want to take a different approach. This particular booklet has a strong emphasis on roles of both calculators and computers in problem solving. By 1980 (and earlier) it was quite clear to me that the focus of computers in education needed to be a focus on roles of calculators and computers as an aid to representing and solving problems. By 1980, the National Council of Teachers of Mathematics had come out strongly in support of use of calculators.

The human race has survived and prospered because of the very capable brains that people have. Among other things, humans are good at accumulating knowledge and skills, and in sharing knowledge and skills with each other. This sharing often occurs in face-to-face settings. But, this sharing also occurs through the tools that are developed and made available to others, and through written language. The past 250 years have bought us the Industrial Age and the Information Age. The tools, including the ICT tools, have significantly changed our world and the lives of people living in this world.

Reading and writing, along with the Industrial Age and Information Age "progress" have led to an exponential rate of growth in worldwide-accumulated data, information, and knowledge. From a problem-solving point of view, this means that there are a steadily increasing number of problems and problem areas that we (collectively) know a great deal about. The "we" here is people and their collected data, information, knowledge, tools, and so on. The exponential rate of growth means a doubling in some modest number of years, sometime currently estimated at perhaps five to ten years. And, the growth is accompanied by a steadily increasing number of problems that people are studying and dealing with.

Now we are getting to the crux of the matter. The nature and extent of the problems that an ordinary person is faced by in everyday life is growing in breadth, depth, and complexity. This is meant to be a strong assertion, so let's think about it a little. The general area of health provides an excellent example. You, personally, know many things about food, vitamins and minerals, medicine, exercise, blood pressure, cholesterol, vaccinations, viruses, bacteria, infections, and so

on than the leading physicians of a couple of hundred years ago. You have accumulated considerable health-related knowledge that is personally important to you. And, you continue to learn more through a wide variety of resources such as your friends, the media, your doctor(s), and so on.

In recent years, the medicine and health information resources on the Web have become one of the most widely used components of the Web. There is a good chance that you have learned to use the Web as an aid to dealing with health-related problems that interest you. In the process of continuing to expand your knowledge of health-related data, information, and knowledge, you have learned that there is far more to know than you will ever know. You read and hear ads and reports from the media. You have learned that doctors and other sources of information are fallible. You have learned about recalls of various drugs that are damaging some people. Perhaps, at times, you feel overwhelmed by your need to deal with health problems.

Now add to that all of the disciplines that you have studied in school or encountered in other ways. My personal conclusion is that there is no way that I can begin to keep up—to learn about and to effectively deal with the data, information, and knowledge from all of these disciplines that is particularly relevant to my life. I believe that this situation describes all people living in our Industrial/Information Age society.

By now you may be asking, what does all of this have to do with calculators, computers, and other aspects of ICT? There are two parts to my answer:

1. ICT is contributing a great deal to representing problems, working to solve these problems, and storing and sharing the results of this work. Thus, people doing this type of research and knowledge-building tasks work need a significant level of ICT knowledge and skills.
2. ICT contributes a great deal to working to automate and/or simplify the processes that people use as they solve the problems that they encounter in their everyday lives, jobs, and soon. Thus, people living in an Industrial/Information Age society need a significant level of ICT knowledge and skills relevant to such problem solving in their everyday lives.

It is the second situation that underlies the purpose of this 25-year old book and my current comments given here. A modern education needs to include a major focus on problem solving situations that a person encounters in their everyday lives. When new tools—in this case, ICT tools—are developed, they are both a source of new problems and an aid to representing and solving old and new problems.

Some of the new tools are so transparent (easy to use, easy to learn how to use) that no school time need be spent in learning to use the tools. For example, I doubt if you needed to take a course in order to learn to use a cell telephone. But, others of these tools take some, and perhaps a great deal of time and effort to learn to effectively use. It is here that formal education can make a difference. And, it is here where our schools are doing poorly.

I'll close with one simple example. In their everyday lives, quite a few people encounter "simple" computation tasks such as adding fractions or calculating the sum of products of pairs of numbers. Some of the former types of calculations are trivial, such as  $1/6 + 1/3 = 1/2$ . Some can be done mentally. Some can be estimated accurately enough to effectively deal with the situation.

And, some require the type of auxiliary or temporary memory aids provided by pencil and paper. As an example, probably you cannot readily do the following calculation in your head:

$$(23.5 \times 14.8) + (16.9 \times 54.3) + (83.6 \times 31.4)$$

Indeed, you might find it to be a reasonably challenging paper and pencil activity, and perhaps you would produce a result that is not correct.

However, this is an easy activity that can be accomplished quickly using a calculator and without use of paper and pencil. That is because almost all inexpensive 4-function calculators have a M+ key and a MR key. Here, M stands for "memory." The calculator has a memory location where it can store an answer, roughly in the same way that you would write down an answer, and then use it later. To do this calculation, key in  $23.5 \times 14.8 =$  and then the M+ key. The result of the multiplication is added to the memory location (which began at zero, if you just turned on your calculator and/or cleared the memory). Continue by keying in  $16.9 \times 54.3 =$  and then M+. The second multiplication is done and the result is added to the current number in the memory. Continue by keying in  $83.6 \times 31.4 =$  and then M+. Finally, key MR (memory recall) and the final answer is displayed.

The same general approach works for adding fractions.

As you can see, it is easy to learn to use the M+ and MR keys to work with the memory location in a calculator. It takes a few minutes of instruction to learn to do this. Most adults who own calculators have not learned to use this feature of their calculators! In my opinion, this represents a (small, easily correctable) flaw in our formal educational system. Also, it means that students are not getting a chance to learn a little bit about computer memory (which is the same as calculator memory). They are getting a school-taught or self-taught knowledge of calculators as "black box" that sort of magically can do routine calculations and calculate square roots. I am saddened by the fact that our school system has not done better over the past 25 years.

This same "black box" approach is being used in much of the computers in education instruction that students are receiving. I strongly believe that we can do better.

David Moursund

January 2005

## **Preface to the 1980 Edition**

Most elementary school teachers are people-oriented, and are not particularly machine-oriented. They are vitally concerned with children, in helping children to develop their potentials and to learn. It is not surprising, then, that many elementary school teachers view computers and calculators with suspicion. Will computers help students to learn more, better, faster? Will use of calculators lead to a better understanding of mathematics and increased problem solving skills? Will calculators and computers dehumanize education? The answers to these questions are both yes and no. Much depends upon the teacher, the student, the equipment, the instructional materials, and so on. The knowledge, attitude, and skills of the teacher are apt to be the dominant factors.

Ten years ago questions about instructional use of calculators and computers were of academic interest, but did not concern the ordinary elementary school teacher. Calculators and computers were too expensive, and were not even readily available in high schools. Their impact upon most elementary schools was zero. But the price of both calculators and computers has declined rapidly, so that now good quality calculators cost under \$10, and computers are beginning to become a common household item. Calculator and computer usage is commonplace in many junior high schools and high schools. It is no longer appropriate for elementary school teachers and elementary schools to ignore their potential uses in instruction.

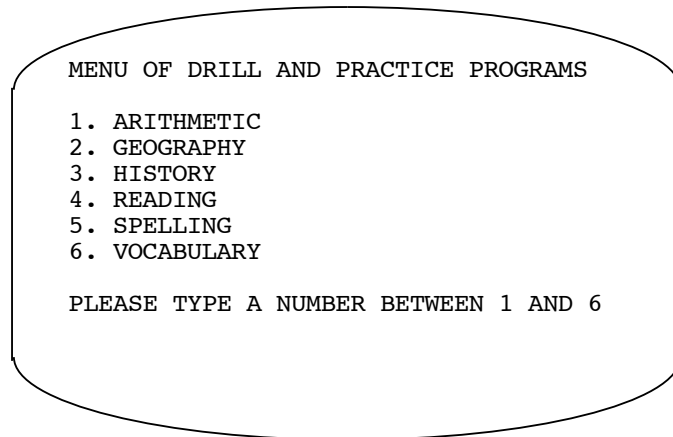
Perhaps the most difficult questions have to do with what children should learn to do mentally, what they should learn to do using books, pencil and paper, and what they should learn to do using other aids such as calculators and computers. The capabilities of these electronic machines continue to grow rapidly and their price is now quite affordable. Thus the whole content of the elementary school curriculum needs to be rethought, and substantial revision may be necessary. This booklet is written for preservice and inservice elementary school teachers who have had no formal training in the computer field. It is designed to help such people gain an initial level of computer literacy and to lay a foundation for additional learning. (Teachers with some computer experience may find the booklet provides a useful overview and some food for thought.) After an introductory section, the main part of this booklet consists of a sequence of questions; each question is followed by a brief answer and by a longer, more detailed answer. The latter part of the booklet is a long section containing sample activities that can be used in an elementary school classroom or in a teacher-training situation. The booklet ends with a Brief Guide to Periodical Literature and a Glossary.

## Introduction

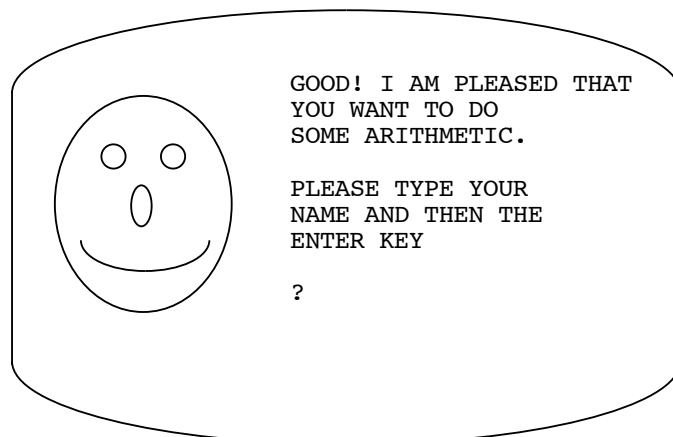
This booklet is written for preservice and inservice elementary school teachers. Thus we will assume that you fall into one of those categories and speak directly to your needs. We will assume that you have used a calculator; it is desirable that you also have had some hands-on experience with a computer. A half hour's interaction with a computer will add substantial meaning to what follows.

Many elementary schools have access to computers for instructional purposes. In the next few pages we describe a hypothetical interaction between a fourth grade student and a computer. The computer might be a self-contained microcomputer, costing \$1,500 or less. Or the student may be interacting with a very large computer via telephone line to a terminal in the classroom.

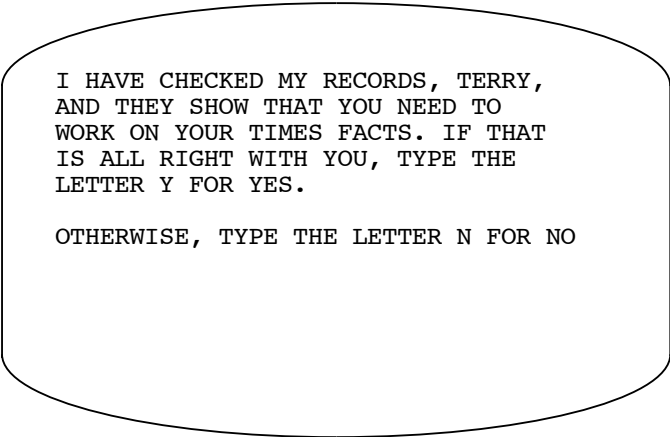
As you walk into the fourth grade classroom you see a student just sitting down in front of a TV set with a typewriter keyboard. You look over the student's shoulder at the TV display screen.



The student is obviously familiar with the computer equipment. Almost before you finish reading the directions s/he types the number 1. The printing on the TV screen disappears, but then is immediately replaced by some more printing.

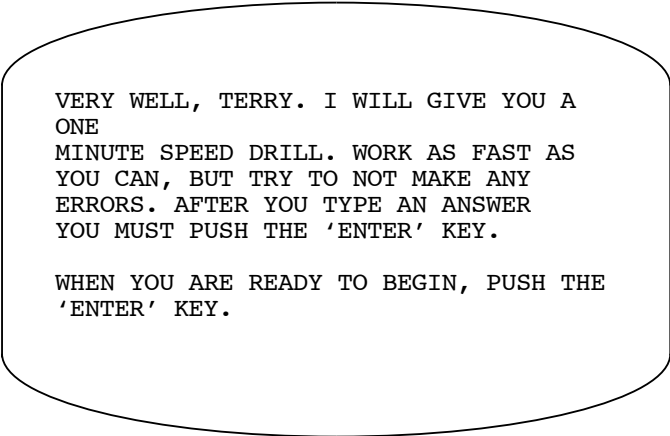


You watch as the student rather laboriously types TERRY JOHNSON and pushes the ENTER key. After a couple of seconds the computer responds.



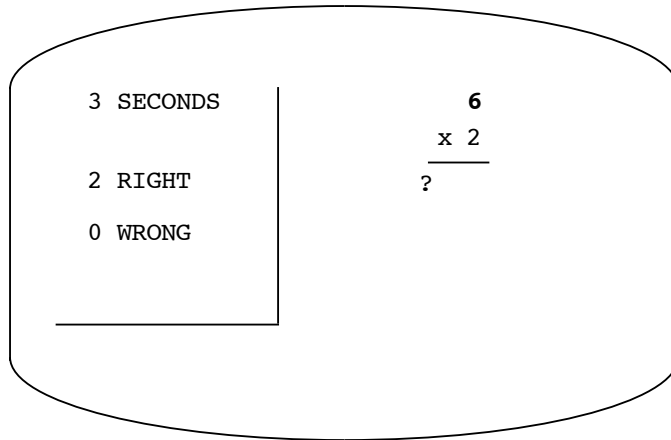
I HAVE CHECKED MY RECORDS, TERRY,  
AND THEY SHOW THAT YOU NEED TO  
WORK ON YOUR TIMES FACTS. IF THAT  
IS ALL RIGHT WITH YOU, TYPE THE  
LETTER Y FOR YES.  
  
OTHERWISE, TYPE THE LETTER N FOR NO

Terry, being an obedient and rather docile student, types the letter Y.

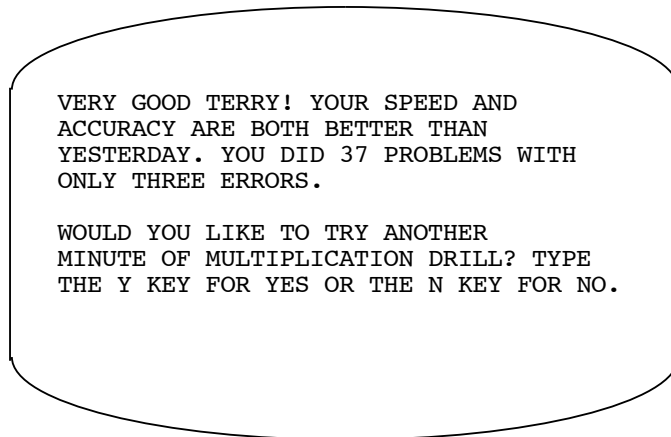


VERY WELL, TERRY. I WILL GIVE YOU A  
ONE  
MINUTE SPEED DRILL. WORK AS FAST AS  
YOU CAN, BUT TRY TO NOT MAKE ANY  
ERRORS. AFTER YOU TYPE AN ANSWER  
YOU MUST PUSH THE 'ENTER' KEY.  
  
WHEN YOU ARE READY TO BEGIN, PUSH THE  
'ENTER' KEY.

You see Terry take several deep breaths, poise one hand over the digit keys on the keyboard, and push the ENTER key. The TV screen clears and a multiplication problem is displayed. Numbers in the upper left corner of the screen begin to count off seconds, and display a scoreboard of Terry's results.

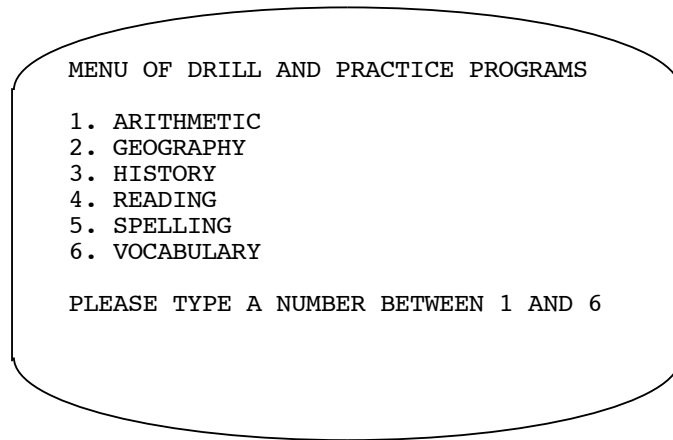


You watch as Terry completes 37 problems in one minute. Each wrong answer results in a "bleep" from the computer, along with a display of the problem correctly solved. You also notice that the same problem appears again a few seconds later. At the end of one minute the computer displays the results.



Terry types the N key and the original menu appears.





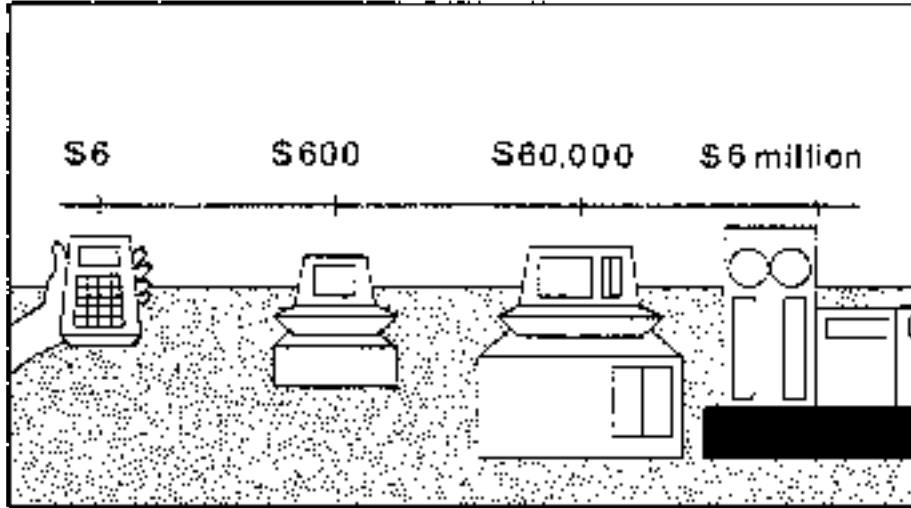
As you continue to observe Terry types a 2 and enters into a geography lesson. The computer draws a map of the western United States and then asks "WHAT IS THE NAME OF THE LARGEST STATE SHOWN ON THIS MAP?" When Terry responds CALEFORNYA the computer responds "YOUR ANSWER IS CORRECT BUT YOUR SPELLING IS TERRIBLE. I SUGGEST YOU SWITCH OVER TO A SPELLING LESSON."

Does this seem like science fiction to you? It isn't. It is a rather routine use of computers as an aid to learning. A few schools have had computer facilities such as this for many years. Now that microcomputers are cheaply available, the use of computers as an aid to instruction in the elementary school is growing rapidly. Computers are now an important part of the daily education of many children. Terry was interacting with the computer in a computer assisted learning (CAL) mode. CAL can help students to learn more, better, and faster. But computers are having other impacts upon the elementary school.

This booklet addresses questions such as "How should the content of the elementary school curriculum change to reflect the capabilities of calculators and computers?" and "What should students be learning about calculators and computers?" The use of computers in education is now a well-established field, and one could well spend a lifetime studying just this aspect of education. Thus this booklet will not teach you all about computers, or all about computers in education. But it will get you started and it will provide a foundation for future learning.

## What is a Computer?

A computer is a machine designed to work with letters, digits, and punctuation marks. Thus it can work with words, numbers, and anything else that can be represented by these symbols. A computer can rapidly and accurately follow a detailed set of directions that has been stored in its memory. It is a general purpose aid to problem solving, with potential uses in every academic discipline.



Graphic by Percy Franklin

It is assumed that you are familiar with a handheld calculator that can add, subtract, multiply, and divide. This is an electronic calculating device, since it runs off of electricity and the calculation circuitry has no moving parts. It is a digital calculating device since it works with individual digits and with numbers represented by a sequence of digits. A handheld calculator is a marvelous device. It is cheap, reliable, useful, and easy to learn how to use. But it is not a computer! Now imagine adding a typewriter keyboard to a calculator, so that it can work with letters and punctuation marks as well as with digits. Imagine automating it, so it can automatically follow an intricate set of directions, and then increasing its speed many fold. Now you have a computer! A computer is a machine designed for the input, storage, manipulation, and output of symbols (digits, letters, punctuation). It can automatically and very rapidly follow a step-by-step set of directions (called a computer program) that has been stored in its memory.

The main emphasis in this booklet is upon computers, but we will also cover the topic of calculators in education. Calculator and computer equipment spans a wide price range, and varies widely in capability. One can buy a handheld calculator for \$6 or less, while the most expensive computer systems cost a million times as much, or more. The cheapest calculator and the most expensive computer have quite a bit in common, since they both make use of electronic components for storing and manipulating symbols. But it should be evident that a cheap calculator is no match for a computer in solving problems that can make full use of a computer's capabilities.

We will study these capabilities and their educational implications. Some of the key ideas are as follows.

1. A computer can store a very large amount of data – useful in solving a wide variety of problems.
2. A computer can automatically follow a very long and very complicated set of directions specifying how to solve a certain type of problem. Large libraries of such computer programs are now readily available.
3. A computer is very fast. Even the least expensive computer can carry out many thousands of program steps per second.
4. A computer is a general purpose aid to problem solving. It is a useful tool in every academic discipline.

This last point is very important to keep in mind. We understand and accept that reading and writing are general-purpose skills, and that pencil and paper are a general purpose tool. Eventually computers will gain a similar level of acceptance, and skill in their use will be expected of all educated people.

At one time calculators were quite expensive, and consequently their potential impact upon elementary school education was low. It was unthinkable that students be given significant access to calculators costing \$1,500 apiece, when most adults could not have similar access. Now, of course, calculators are commonplace in homes, stores, and wherever calculation needs to be done.

The price of a microcomputer is now about what calculators cost in the mid 1960's. While computers will never be as cheap as handheld calculators, their price continues to decrease. They are increasingly available in homes, businesses, and in education at all levels. Over the next 20 years they will have a massive impact upon education.

## What is Interactive Computing?

Early models of computers could be used by only one person at a time, and little or no interaction between the user and the machine could occur while the machine was working on a problem. The development of timeshared computing allowed many people to simultaneously share a computer's facilities, and to interact with the machine as it worked on their problems. In the mid 1970's a new type of computer, called a microcomputer, was developed. It is designed to be used in an interactive mode, but by only one person at a time.



Graphic by Percy Franklin

The first general purpose electronic digital computer became operational in December 1945. It contained 18,000 vacuum tubes, filled a very large room, used an enormous amount of electricity, and required extensive air conditioning. To set up the machine to work on a particular type of problem might take a week or more. Thus a very limited number of people were able to use the machine to help solve their problems.

Computers first became commercially available in 1951, and transistorized computers became common starting in 1958. Thus machines became smaller, more reliable, and required less electricity and air conditioning. Still, only one person could use a machine at a time, and the setup time between jobs remained a problem. There was little or no opportunity for a person to interact with the machine while it was actually solving a problem. Two developments during the 1960's had a major impact upon the computer field. First came the idea of sharing a computer's resources among a number of simultaneous users. The machine is designed to handle a number of input and output units, and to interact with a number of simultaneous users. This is called timeshared computing, or INTERACTIVE computing. A timeshared computer network can also serve as a communication system, and that idea is now commonly used in modern business communication systems.

The second development was the integrated circuit. The same ideas used to manufacture a single transistor could manufacture a circuit containing dozens or even hundreds of transistors and other components. These are manufactured on a small piece of silicon, called a chip. Progress in chip technology led to the capability of building very complex circuits from a small handful of chips, plus appropriate connectors and power supply. Moreover, since these chips

became cheaper and cheaper to manufacturer, the price of computers decreased rapidly. Going into the 1970's, then, we had two main types of computer systems. The timeshared system was designed to allow a number of simultaneous interactive users, and shared its central memory and computing facility among these users. Alternatively, there were one-user-at-a-time systems, called batch processing systems. The setup time between users was reduced to a few seconds or less in many cases.

The early 1970' s saw the introduction of smaller, less expensive computers, called minicomputers. Such machines began to be used in secondary schools, and became commonplace in higher education. Chip technology continued to progress, and the mid 1970's saw the introduction of microcomputers—machines whose electronic circuitry was based upon a very small number of chips. These microcomputers are so inexpensive that they can be used in a combination batch processing-timeshared mode. Thus a single user has full control of the machine over an extended time span, and interacts with it much in the manner of interacting with a timeshared system. The user has some of the advantages of both a batch processing and a timeshared system, but also certain disadvantages. The communication between simultaneous users of a timeshared system is lacking. The large storage capacity and versatility of larger computers (typically available on both batch and timeshared systems) is missing. Still, microcomputers are revolutionizing the field of computers in precollege education. Their price is sufficiently low so that every school system can afford to provide some computer facilities to its students. The interactive nature of microcomputers has proven to be an excellent aid to education.

All teachers understand that students need feedback to help them learn. This feedback can be provided by a teacher, other students, answer sheets, and so on. An interactive computer system is an excellent feedback mechanism. It can digest and process complex student responses, and then provide feedback appropriate to the situation. It is the interactive aspects of computers that provides the potential for a revolution in instruction.

## What is Computer Hardware?

A computer system consists of physical machinery (called hardware) and programs (called software). Both are needed if a computer system is to perform a useful task. The key hardware components are given in the diagram. They include input unit(s), output unit(s), memory, and a central processing unit.



Graphic by Percy Franklin

When one looks at computer one sees the hardware—the physical machinery. Every general purpose computer system has five major hardware components.

**Input unit(s):** To get information into the computer. The most common input unit is an electric typewriter device called a keyboard terminal.

**Output unit(s):** To get information out of a computer. The most common output devices are a television display screen (color, or black and white) and a typewriter-like printing mechanism.

**Primary storage:** Contains a program while it is being executed, and contains the data being processed.

**Central processing unit:** Figures out the meaning of the instructions in a program, and carries them out very rapidly.

**Secondary storage:** Provides permanent, inexpensive storage of large libraries of computer programs and large quantities of data.

The least expensive microcomputer systems, costing under \$500, have all five of these components. For an inexpensive microcomputer system the input unit will be a typewriter-style keyboard, perhaps molded into a cabinet containing a television display screen. The output unit is a television display screen, perhaps specially modified to improve the quality of the display. Secondary storage is a cassette tape recorder, using inexpensive cassette tapes. The central processing unit is a single chip, called a microprocessor. Such chips may cost less than \$10 apiece when mass produced. The primary storage is relatively limited in total storage capacity, and is manufactured using chips.

A key aspect of computer hardware is its speed. Even the least expensive microcomputer can execute many thousands of instructions per second. The most expensive computer systems are perhaps a thousand times as fast as microcomputers, being able to execute tens of millions of instructions in one second.

One measure of the capability of computer hardware is the capacity of primary storage. This type of memory is relatively expensive, since it must function at the same high speed as the central processing unit. On an inexpensive microcomputer system one expects to find a primary storage capacity of between 8,000 and 64,000 characters (that is, letters, digits, or punctuation marks). A large computer system will have a primary storage capacity several hundred times as large.

The large scale computer system has a number of additional hardware features that help to improve its overall capability. For example, it will have a line printer that is many hundreds of times as fast as an electric typewriter. Printing speeds of many thousands of words per minute are possible. It will have very high quality, large capacity, magnetic tape units. It will make extensive use of disk storage units, which are flat circular plates coated with the same material used on magnetic tapes. The total secondary storage capacity of the system may be comparable to a large library - that is, the equivalent of hundreds of thousands of books.

There are many input/output devices that can contribute to making a computer system a good educational tool. Very young children can learn to use a keyboard terminal. But a touch panel, which recognizes which spot on a display screen has been touched, may be more appropriate to their needs. Similarly, a bit pad, which allows a drawing to be entered into a computer, is a useful educational tool. Many computer systems have an audio output device, perhaps one that can make a buzzing noise. But some computer systems can output a full range of musical tones as well as the human voice. Also, voice input to computer is now quite feasible. It should be recognized that the variety of input/output hardware mentioned above costs money, although not an unreasonable amount. Also, this hardware is useful only if appropriate computer programs (software) are available. Software is discussed in the next section.

A recent, very exciting addition to computer hardware is the videodisc. Designed initially for the storage and playback of television programs, the videodisc is also an excellent secondary storage device for computers. A laser readout, computer controlled videodisc system can store 50,000 pictures—the equivalent of a half hour of motion pictures. Under computer control one can get random access to single pictures and/or show the materials at various speeds, forward or backward. The videodisc system has two sound tracks, useful in bilingual instruction and for other purposes. Eventually videodiscs will help bring high quality computer assisted instruction into homes and schools throughout the country.

## What is Computer Software?

A computer program is a detailed step by step set of instructions specifying how to solve a certain type of problem. The terms "computer program" and "computer software" mean the same thing. A computer can solve a problem only if appropriate software is available. In the United States alone, nearly a half million people are involved in the occupation of writing computer software. These people are good at figuring out how to solve problems and at writing detailed sets of instructions. They must have good knowledge of the subject matter of the problem area. A very important aspect of computers is that computer software can be stored in a library, typically in a computer's secondary storage hardware. This software is then available for people to use - people who did not write the programs. Thus one can use a computer without knowing how to write programs. This is essential to the elementary school, where neither the typical teacher nor the typical student has the knowledge to develop the needed software.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

Computer programs are written in computer languages such as BASIC, COBOL, machine language, or PASCAL. Programming languages are discussed in the next section of this booklet. At one time the primary cost of using a computer was the cost of the hardware, but now software is often the dominant cost. Of course, the same software may be used by thousands of people, in which case its cost may be spread out over a large number of people.

To better understand software, we need to understand two things:

1. What types of steps or operations can a computer's CPU carry out?
2. What is involved in writing software to solve a particular type of problem?

A computer is a machine designed to work with symbols, such as letters and digits. A computer's CPU can move these symbols between various primary and secondary storage units; it can accept these symbols as input and produce strings of symbols as output. It can combine letters to form words or digits to form numbers. It can add, subtract, multiply, and divide numbers. It can decide if two symbols are the same, or if a letter comes earlier in the alphabet than another letter. A CPU is not "intelligent" like a human being. It merely mechanically and rapidly carries out certain simple manipulations of symbols.

If a computer is to solve a problem or help solve a problem then its CPU must be told precisely what it is to do. Thus a human being must figure out how to solve the problem and also figure out what to tell the computer to do. A computer programmer is a person who knows how to solve problems, and who is good at writing detailed sets of instructions in a form that a computer can follow. Thus a programmer must have good insight into the capabilities and



limitations of a computer's hardware and its programming languages. Equally important, a computer programmer must understand the subject matter field containing the problem. For example, if s/he is to write a program to solve a business problem, the programmer is apt to need to know a lot about business.

A very key concept, however, is that people other than computer programmers can use computers. Once a program has been written to solve a particular type of problem, it can be stored in a computer library. This means that it is placed into a computer's secondary storage system, and can easily be brought into primary storage for use as needed. One does not need to know how to write programs in order to make use of a program from a computer library. Very young children can easily learn this aspect of using a computer. It is not much more difficult than using a TV set or a record player.

The educational implications of this are immense. A major goal of education is to help students learn to solve a wide variety of problems. Now we have machines that can solve many of these problems. The capabilities of these machines continue to grow as more and better programs are written, and as better hardware is developed. If a computer can solve a certain type of problem, what do we want people to know about solving the same problem using pencil and paper, or mentally?

One quite important branch of computer science is called artificial intelligence. It deals with how smart a computer can be—can it do intelligent-like things? Computers can play complex games such as checkers and chess quite well. They can perform medical diagnoses, carry on a conversation, and aid in foreign language translation. Progress in artificial intelligence research is continually expanding the horizons of computer capabilities. Needless to say, artificial intelligence has the potential to have a significant impact upon education.

One of the most complex problems faced by our society is helping students to learn. Writing computer programs that will help students learn is not an easy task. Fortunately, there are now many professional educator-programmers who are working on the problem. The supply of commercially available, high quality educational software is gradually expanding. Currently, however, there is a shortage of software designed to fit the wide variety of instructional needs that exist in elementary school education.

Remember that a computer program is a detailed set of directions, telling what to do at all stages of solving a certain type of problem. Suppose that the "problem" is to help a student learn reading or arithmetic. Do we know enough to mechanize the process? It is easy to see from this question why it is difficult to develop good quality software for use in elementary education. One needs to know the subject matter, learning theory, children, and the computer. Because of the broad range of knowledge and talents necessary, software is often developed by teams. A team might consist of a teacher, a media specialist, a learning theorist, and a computer programmer. Such a team, properly experienced in working together, can produce very high quality educational software. But because of the large amount of labor involved in its development, good quality educational software tends to be quite expensive.

## What are Programming Languages?

The CPU of a computer "understands" (that is, can interpret and carry out) perhaps 60 to 300 different instructions. This is the machine's "machine language," and different brands or models of computers generally have different machine languages. A number of "universal" languages, with names like BASIC, COBOL, LOGO, PASCAL, and PILOT have been developed. Programs written in these languages can be used on a wide variety of makes and models of computers. This is made possible by certain translating programs, which translate from these languages into machine language. A different translating program is needed for each programming language, and also for almost every different make or model of computer.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

Without appropriate software a computer can do nothing. Thus a major aspect of the history of computers is the development of better aids for programmers. Programming in machine language is slow and error prone. Programs written in the machine language of one machine will not run on a machine with a different machine language. Out of this difficulty arose the idea of "higher level" languages - programming languages that would be independent of any particular machine.

Beginning in the 1950's computer scientists have developed a large variety of these higher level languages. FORTRAN was developed for scientists, COBOL for business people, BASIC for college students, LOGO for elementary school students, and PILOT for educators. New languages have been developed as computer scientists gain better insight into the capabilities and limitations of computers and the particular people who will use the languages. A language designed to fit the needs of a first grade student is not apt to fit the needs of a research scientist. A language designed to aid in music composition is not apt to fit the needs of an architect.

The language BASIC was developed at Dartmouth College in the early 1960's to meet the interactive computing needs of college students. Since then the use of BASIC has grown rapidly, so that it is the most widely used language in education at all levels. This in no sense implies that it is the best language for use in precollege education - merely that currently it is the most used language. If a language such as BASIC is to be used on a particular computer then there must be a translating program, which translates BASIC statements into that machine's machine language. The sample BASIC program given below can be run on dozens of different types of computers because dozens of different translating programs have been written for BASIC.

```
100 REM *** PROGRAM RECTANGLE ***
110 REM * DESIGNED TO ILLUSTRATE PROGRAMMING IN BASIC
120 REM * PROGRAM WRITTEN BY DAVID MOURSUND
130 REM *           VARIABLES
140 REM *           A = AREA OF A RECTANGLE
150 REM *           L = LENGTH OF A RECTANGLE
160 REM *           W = WIDTH OF A RECTANGLE
170 REM *           P = PERIMETER OF A RECTANGLE
180 PRINT "THIS PROGRAM WORKS WITH RECTANGLES."
190 PRINT "YOU SUPPLY THE LENGTH AND WIDTH, AND"
200 PRINT "THE COMPUTER DETERMINES AREA AND PERIMETER."
210 PRINT "WHAT IS THE LENGTH OF THE RECTANGLE?"
220 INPUT L
230 PRINT "WHAT IS THE WIDTH OF THE RECTANGLE?"
240 INPUT W
250 REM * USE FORMULAS TO COMPUTE THE AREA AND PERIMETER.
260 LET A = L * W
270 LET P = 2*L + 2*W
280 PRINT "THE AREA OF THE RECTANGLE IS"; A
290 PRINT "THE PERIMETER OF THE RECTANGLE IS"; P
300 PRINT
310 PRINT "WOULD YOU LIKE TO SOLVE ANOTHER RECTANGLE (YES, NO)"
320 INPUT R$
330 IF R$="YES" THEN 210
340 IF R$="NO" THEN 370
350 PRINT "YOUR RESPONSE IS NOT UNDERSTANDABLE."
360 GO TO 300
370 END
```

When this program is run on an interactive computing system it will print out directions to the user, request values for the length and width of a rectangle, and then compute and output its area and perimeter. The user of the program does not need to remember the details of how to solve the problem. The program can be used to solve a sequence of rectangle problems, and it halts when the user indicates there are no more rectangles to solve.

A single computer can "understand" any number of different languages. All that is necessary is that the appropriate translating programs be written. But writing a translating program may take several years of a full time, very skilled, programmer's effort. Thus translating programs are quite costly. The manufacturer of an inexpensive computer system is apt to provide translators for one or two languages. The owner of the machine may need to purchase additional translators, or pay to have them developed, if s/he wants to have other languages available for use on the machine.

Students at all grade levels can learn to program, provided that appropriate computer facilities, teaching and learning aids, and trained teachers are available. Some instruction in

computer programming is an essential part of developing computer literacy. It takes a substantial amount of instruction in computer programming to develop a functional level of skill, such as would be useful in writing programs to solve problems in a variety of disciplines. Thus computer programming as a part of computer literacy might be part of a quarter or half year computer literacy course in a junior high school, while computer programming to develop a useful skill level might be incorporated into a year long senior high school computer science course.

At the current time there are very few elementary school teachers who are qualified to teach computer programming. There are few instructional materials suited to the needs of elementary school students or teachers. Moreover, there is little agreement as to whether students at this level should be taught to write programs. It seems likely that eventually there will be programming languages that are well suited to the needs of young students. If teachers become skilled in the use of and instruction in these languages, then perhaps computer programming will eventually become a standard part of the elementary school curriculum.

We mentioned earlier that LOGO is a language that was designed for use by young students. It was developed by Seymour Papert at Massachusetts Institute of Technology. Using this language students can draw pictures on a TV screen, solve problems involving words and numbers, and so on. If appropriate output devices are available they can cause a mechanical turtle to move around on the floor, ring a bell, or program an electronic organ to play music. The computer equipment creates an interesting and "rich" problem solving environment. Papert feels that students who are immersed in this environment will develop their problem solving skills and will be strongly motivated to learn to program a computer. His research findings support this position.

## What Are the Main Categories of Educational Use of Computers?

The educational use of computers can be divided into administrative, instructional, and research uses. Higher education in the United States spends about 3% to 4% of its entire budget on computing, with funds fairly evenly distributed among these categories. The typical precollege school system spends 1% to 2% of its budget for computing. Generally administrative use currently far exceeds instructional use, and there is relatively little research use of computers in school systems. Very few school districts in the United States currently spend as much as 1% of their budgets for instructional use of computers. However, this type of usage is now growing quite rapidly.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

It is assumed that you are most interested in instructional uses of computers, so the next three sections of this booklet are devoted to various instructional aspects of computers. In the current section we discuss administrative and research uses of computers in education.

Almost all school districts in the United States make administrative use of computers. Detailed records must be kept, and reports must be filed with the state government. Teachers must be paid, and tax records must be filed with the federal government. Student records must be maintained, and grade reports must be sent to parents. Inventories of supplies, books, instructional materials, etc. must be maintained and accounted for. All of these tasks can be accomplished using "by hand" methods. But often use of a computer accomplishes the task cheaper, more accurately, and more rapidly.

School administrators need rapid access to accurate information to aid in decision making. The idea of a computerized management information system is now common in business and industry, and is gradually coming into school systems. Data that may be needed for decision making is collected and stored in a computerized information retrieval system. Software is developed to allow the processing of this data. With a good computerized management information system an administrator can easily get answers to "what if" questions, such as "What if Bus #7 doesn't run today due to snow?" or "What if substitute teacher's salaries are raised 15%?" Because computers are such useful aids to school administrators we can expect their use to increase rapidly in the years to come.

Computers are an essential tool to research in higher education, with about one-third of higher education computing budgets being used for this purpose. Relatively little research goes on in precollege educational systems, and hence little money is spent for computer usage in this category. But this type of usage is growing. We will cite two examples.

The United States government helps fund a number of educational research information centers, called ERIC centers, which subscribe to almost every educational journal and which seek out literature on educational research. These centers hire people to write summaries of the research articles and to index the articles. All of this information is put into a computerized information retrieval system, and hence made easily available to researchers.

For example, suppose you were interested in bilingual, bicultural education in the elementary school. A computerized search of this topic in the ERIC data bank might cost \$15. In a few minutes you could receive titles and brief abstracts of a number of current articles in this area. The same computer system can even be used to place an order for microfilm copies of the articles! There are now hundreds of computerized data banks of bibliographic information. Moreover, major libraries, such as the Library of Congress, have switched to a computerized replacement of the card catalog systems.

A second typical research use of computers is in the statistical analysis of educational data. A school system decides to institute a special program of instruction in some of its schools. Tests are administered to students entering the special program as well as to a control group of similar students who will not be in the special program. Later all of these students are tested again, and compared to see what types of changes have occurred. Computers are an essential tool to working with large sets of data and performing the necessary statistical analysis.

Both administrative and research use of computers in education illustrate an important point. Computers are a tool that may be useful in attacking certain problems. Usually these problems are already being handled by some other (non computerized) means. Thus one has a choice—to use or not to use a computer. The decision to use a computer should be based upon a careful study that considers the advantages and disadvantages of computer usage. Merely because a computer can be used to help accomplish a specific task does not mean that it should be. Keep this idea in mind as you study various instructional aspects of computers.

## What Impact Should Computers Be Having On the Current Curriculum?

The first and foremost goal of education is to give students the tools, skills, and knowledge to cope with the types of problems faced by people in our society. Both professional educators and the general public agree that reading, writing and arithmetic are essential to understanding, representing, and solving problems.

From early on humans have devised and used tools to help solve problems. Now calculators and computers have developed—mainly to help solve adult types of problems. Elementary school education must decide role these what machines will play: what students will learn to do mentally, what they will learn to do using simple tools such as paper, and what they will learn to do using tools such as books, calculators, and computers.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

Calculators and computers are an everyday tool of adults working in business, government, and industry. Our educational system has yet to understand the educational implications of this fact. Changes need to be made in our curriculum even if we are not yet able to make calculators computers readily available to all students.

While education has many goals, it is generally a important one is to give students the tools, skills, and with the types of problems faced by people in our society. Thus we have a major emphasis upon the three R's, and upon learning to learn.

It is problem solving, and learning to cope with a wide variety of problems, that is at the heart of education. The major steps involved in problem solving include:

1. Understand the problem. Here reading and listening are essential skills, and overall general education plus common sense are important.
2. Figure out a plan to solve the problem, and represent the plan. Here thinking, drawing upon previous knowledge, and writing are essential skills. One (new) way to represent a plan is in the form of a computer program.
3. Carry out the plan. Often this is a routine and rote task. Speed and accuracy are desirable, while perseverance and attention to detail are often necessary.
4. Understand the meaning of the results, check to see if they make sense, and make use of the results. This is a thinking task, drawing upon previous knowledge and one's understanding of the problem to be solved.

Of these four steps, the easiest to teach and the easiest to test on standardized tests is step 3. Also, it is evident that this step is essential if a problem is to be solved. Thus it is not surprising

that our schools place great emphasis upon developing skill in carrying out routine tasks. But this is precisely what calculators and computers do best!

We can gain insight into the overall curriculum impact issue by considering calculators in the elementary and middle school. It takes a number of years of instruction and practice for students to master paper and pencil algorithms for multiplication or division of numbers containing decimal fractions, or for calculating a square root. There is a clear difference between understanding the concepts of these operations (what problem is being solved, why does one want to solve it) versus mastering a paper and pencil algorithm. Calculators provide an alternative. Perhaps it is not a necessary or appropriate use of school time to have students master those paper and pencil algorithms. Perhaps the time might better be spent in improved mental arithmetic skills, better understanding of what problem is being solved, and more experience in problem solving.

The electronic digital watch and clock provide another interesting example. Young children can learn to "tell time" (state the numbers representing the time) very easily from a digital readout. But clearly this is different from "understanding" time or solving problems related to time. Thus a digital watch does not solve the problem of teaching students about time any more than a calculator solves the problem of teaching students arithmetic. But both the digital watch and the calculator are valuable tools, and each requires that some rethinking/restructuring be done in the curriculum.

The ready availability of computers broadens the scope of areas in which curriculum revision may be necessary. Word processing (a computerized typewriter) provides an interesting example. A modern word processing system consists of a keyboard terminal, a TV display screen, a typewriter-quality printer, and a secondary storage device such as a magnetic disk. Material is typed into the computer and displayed on the TV screen. Corrections are easily made. The computer can even be asked to check for possible misspelled words! Then the material is printed out on paper using the typewriter printer.

A word processing system greatly increases the productivity of a writer or secretary. Its potential impact upon students learning to write is quite large. Should typing be taught in the elementary school? If a computer can check one's spelling, does spelling remain at its current level of importance? How important is good penmanship if typewriters or word processing systems are readily available?

Still another interesting example is provided by a computer system attached to a music synthesizer. It may well be that many young children have the capability of composing music. But most don't develop this talent, since they lack the skills to perform or represent the music they can create in their minds. An interactive computer system can solve both of these problems. The use of such equipment in the elementary school curriculum might significantly change music education.

We have machines throughout our society, such as the car, train, airplane, typewriter, telephone, radio, television, telescope, and microscope. Our educational system teaches students to work with these machines, rather than to compete with them. So it will eventually be with calculators and computers. Our overall curriculum needs to change, to reflect the role that calculators and computers best play in problem solving. This means that we must decrease the emphasis upon the routine and rote skills of carrying out a plan to solve a problem. We need to place increased emphasis upon the higher-level skills of understanding, figuring out how to solve



problems, representing plans to solve problems, and understanding the meaning of results produced when these plans are carried out.

Two points need to be made clear. First, paper and pencil remain an essential tool—it is merely routine and rote paper and pencil manipulation that is decreasing in importance. Second, there is increased need for accurate and rapid mental skills, such as knowing the basic number facts and knowing how to spell and punctuate. What we need to do is prepare our students to work with the computer tool, rather than to compete with it.

## **How Are Computers Used as an Aid to Instruction?**

The use of computers as an aid to instruction has been extensively researched over the past 20 years. There is substantial evidence that computers are an effective instructional delivery system. That is, with a broad range of conditions, students, and subject matter, students learn better and faster with computers as compared with "traditional" instructional delivery systems. This is highly dependent, of course, upon having adequate and appropriate computer software and hardware. Since software and hardware can be quite expensive, the cost effectiveness of computer assisted learning is often questionable. But the low cost of microcomputers make computers a feasible aid to instruction.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

The overall field of teaching and learning using computers is called computer-assisted learning (CAL). Development and research in CAL began in the late 1950's. There have been several large federally funded projects and literally thousands of smaller CAL projects that have been carefully studied and reported on in the literature. For example, the PLATO project began at the University of Illinois in 1959 and is now commercially distributed by Control Data Corporation. Pat Suppes of Stanford University began to develop drill and practice materials for the elementary school in the 1960's. United States, distributed by the started by Suppes. Not every CAL project is successful. But in the overwhelming majority of cases students learn better and faster.

Until the advent of microcomputers, CAL was too expensive for widespread implementation in ordinary public schools and the home. Thus the great majority of CAL has been in medical schools, armed services education, remedial education, and so on where the cost of traditional education is high. Microcomputers have allowed two major changes. First, they have reduced the cost of hardware needed for CAL. by a significant factor. Second, they have broadened the potential audience (hundreds of thousands of microcomputers have been sold). This allows the cost of software development to be spread over a larger number of users and makes the commercial development of CAL materials economically feasible.

Computer assisted learning is often broken into three parts, only two of which are apt to occur in an elementary school setting. Computer augmented learning is the easiest, quickest, and probably the cheapest instructional use of computers to implement. The idea is that students write programs and/or make use of computer library programs to help solve the types of problems that arise in various academic studies. Since large libraries of such programs have been developed by use of people on the "real-world" (that is, people who have need to solve the problems on the job) such software is readily available. Students can learn to use it with a minimum of training, and the amount of teacher training that is needed is minimal. Computer augmented learning is quite common at the college level, and is beginning to creep into high

schools. But elementary school students tend not to have much knowledge of real-world problems that would require a computer for solution, nor do they have programming skills. Thus computer augmented learning is not of particular concern to elementary school teachers.

Computer managed instruction is any application of computers to classroom management or teacher support functions. A computer can score a multiple choice test, perform an item analysis on the results, and even print out individualized diagnostics for students. A computer can store grade records and print out summary statistics. A computer can keep track of each student's standing and progress in an individualized program of study. A computer can generate tests, and administer them to students in an individualized interactive fashion.

Computer managed instruction can aid teachers in much that is burdensome, time consuming, and relatively unrewarding in teaching. But it requires extensive software, keyed to the particular subject matter and instructional materials being used in the classroom. By and large this software is not currently available for elementary school education. Only slowly will it be developed, and initially it will be keyed to traditional nationally sold textbook series. Several major publishing companies are developing such computerized supplements to their textbooks.

Computer assisted instruction (CAI) is the use of computers to present instruction to students. It is the interaction between a computer system and students to help students learn new material or improve their knowledge of materials previously studied. At its simplest level much CAI is merely rote drill and practice, with the computer serving as a drill master and record keeper. There are many cheap alternatives to this, such as flashcards, students drilling each other, and handheld calculator-like arithmetic drill machines. Still, CAI drill and practice is a very effective aid to learning. At a more sophisticated level CAI can be thought of as a programmed text. Various materials are presented to the student based upon the correctness of answers to questions previously presented by the machine. A student's rate of progress is governed by his/her rate of learning the material. At the most sophisticated level there exist dialogue systems, in which the computer and student interact in higher level problem solving activities. Often these are computerized simulations of real-world problems, such as controlling water pollution, running a nuclear reactor, fighting an insect infestation, running a business, and so on. Many of these simulations are quite realistic; interacting with them is exciting, and results in substantial learning.

CAI is a direct challenge to teachers and to much of traditional education. As more and more good CAI materials are developed and proven effective in widespread use, the current role of teachers in education will come under attack. Students will be able to have inexpensive, patient, interactive, personalized tutors to use at home, in public libraries, and in school settings. AI Bork, one of the leading proponents of CAI in the United States, predicts that by the year 2000 more than half of all instruction in this country will be via computer.

One can think of computer assisted learning as a further step in the automation of education. (Certainly books and the printing press represent earlier steps.) Undoubtedly it will disrupt the current, traditional system, and eventually it could displace some teachers. It seems likely that this will occur rather slowly - indeed, almost all changes in education occur rather slowly. Also, it should be recognized that teachers play many roles in education. While CAL can help fill some of these roles, it makes little or no contribution to others. The loving, caring, feeling teacher will be needed more than ever. The net effect can be that schools get better. Much will depend upon

the knowledge and other attributes of the individual teachers who ~re involved during this time of change.

## **What Should Elementary School Students Learn About Computers?**

Leaders in the computers in education field agree that all precollege students should become computer literate. This means they should learn about the capabilities and limitations of computers; they should learn the social, vocational, and educational implications and effects of computers.

Two levels of knowledge are important in precollege education. First is an awareness level. Second is a working-tool, or functional level. An awareness level can begin to be developed in elementary school, and can be integrated into each subject matter the student studies. A functional level requires specific instruction in use of a computer. It includes substantial hands-on experience, both in using existing library programs and in writing programs to solve problems. There is a still higher level of computer knowledge—the professional level. Training to be a computer professional is currently carried on mostly at the post-high school level, although a few high schools offer some professional level of training.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

The question of what students should learn about computers has been studied by many professional groups over a period of years. There is nearly universal agreement that all students should become computer literate. But computer literacy is a nebulous concept; there is not universal agreement as to its meaning.

Historically, computer literacy tended to refer to an awareness level of computer knowledge. Students would read about computers, and learn about their capabilities, limitations, and applications. They would gain insight into how computers are affecting the world, and the vocational/ educational implications of this upon individual students. This point of view was strongest when computers were still quite expensive, and it was not feasible to make hands-on experience available to most students.

Gradually educators have come to realize that computers are even more important than first suspected, and that students at all educational levels can learn to use a computer as an aid to problem solving. This has been coupled with the development of microcomputers and a continued rapid decrease in the price of computer hardware. As computers more and more become an everyday tool of millions of people it has become clear that we must raise our sights.

Nowadays the goal of universal computer literacy is a goal of a working knowledge—a functional level of knowledge about using computers. Progress towards this goal can begin in the elementary school.

Suppose, for example, that an elementary school has 250 to 300 students in grades 1-6. The school has three microcomputers housed in the library or learning center, and a library of software appropriate to the needs of its students. A person working in the library or learning center knows the rudiments of using the microcomputers, and who to contact if maintenance or repair is necessary.

If the three microcomputers are fully used during school hours then a total of about 2700 hours of contact time, or nine hours per student per year, is available. How can this computer time be used to help raise the computer literacy level of students? Clearly an average student access of one hour per month is not going to have a significant impact upon a student's overall instructional program. That is not enough computer access for a significant CAI program. But the following goals could be accomplished.

1. Beginning at the first grade level every student will learn to check out a program disk or tape from the program library, turn on the computer system, load a program, run a program, and return the tape or disk to the program librarian.
2. Each month every student will have 15-20 minutes of use of drill and practice materials on a computer. The materials should be in a variety of subject matter areas and suited to the level of the student. Thus students will experience computerized drill in arithmetic, geography, history, spelling, vocabulary, and so on.
3. Each month every student will have 15-20 minutes of use of an interactive simulation/game designed to help students learn some subject matter. These will be chosen to reflect a variety of subject matter areas and types of simulations.
4. Each month every student will have 15-20 minutes of use of a microcomputer for recreational purposes. The student should have the choice of a variety of games suited to his/her hand-eye coordination, mental skills, and interests.

The overall result of this program of computer usage is that each student will learn to use a computer in a wide variety of application areas, and (probably) enjoy the overall process. A later section of this booklet contains a number of sample activities that can be carried on in a classroom. These can be backed up by appropriate movies or other media aids. They will contribute significantly to student awareness of computers.

The schedule of microcomputer usage listed above is based upon a five hour day, 180 days per year. If students can have access to the machines before and after school, during the lunch period, and evenings or weekends, substantially more hands-on experience is possible. If a teacher in the school has a significant level of computer knowledge then a computer class might be offered to some students, or a computer club might be started.

The plan just discussed should not be taken as an ideal model. It represents one possible starting point, assuming a certain level of computer accessibility and a low level of teacher knowledge. If the school had only one microcomputer, the plan could be followed for 5th and 6th graders. With two microcomputers the plan could be used with students in grades 3-6. If more computer facility is available then CAI becomes feasible.

Over a period of time one can expect that both computer accessibility and teacher knowledge will grow. If a school system decides that CAI should be used, a considerably higher level of computer access will be necessary. In a typical CAI setting, some specified group of students have everyday access to a computer. For example, it is common to have students drill on

arithmetic or on language art skills for 10-15 minutes each day. When the computer is not being used for CAI purposes it can be used to allow increased computer access by all students in the school.

## **What Role Should Calculators Play in Elementary School Education?**

Although the dividing line between calculators and computers is not very distinct, calculators are primarily an aid to performing mathematical calculations. Thus, their greatest impact is upon the math curriculum. The National Council of Teachers of Mathematics strongly supports their use throughout the school curriculum.

At the elementary school level students can become familiar with calculators and begin to develop skill in their use. Limited and judicious use of calculators here can free up some time that can be spent on the "thinking" and other higher cognitive levels of activities needed in mathematical problem solving. This calculator usage can change the overall flavor or direction of the mathematics curriculum.

Because the calculator has many computer-like features, it is a useful aid in introducing certain computer topics. For example, the memory in a calculator with 4-key memory is quite similar to a computer's memory, and the calculator number system is similar to the computer number system.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

Calculators and other electronic aids to mathematical calculation are now an everyday tool of most adults who need to do calculations. Perhaps 30 million calculators a year are being sold in the United States. Some are so small that they are as easily carried as a credit card. An electronic digital watch with a built in calculator now retails for under \$50. Some major educational issues are:

1. What should students learn about calculators?
2. When should they learn it?
3. When should students be allowed to use calculators?

The often-voiced fear is that widespread student use of calculators will lead to a dependence upon these machines, and a decrease in paper and pencil or mental arithmetic skills. The use of calculators has been studied in hundreds of research projects, and the results tend to allay the fears. Use of a calculator does not cause a student's brain to atrophy. Judicious use of calculators does not damage the curriculum - indeed, can contribute substantially to it.

At the primary school level (grades 1-3) calculators have only modest value. They are an additional math manipulative, an exploratory tool. Their occasional use can provide additional variety in the curriculum, and can serve as an aid to learning topics currently taught at this level.



Primary grade students enjoy playing with calculators, and many consider them to be delightful toys.

During the primary grades students develop a concrete and intuitive understanding of the four basic arithmetic operations. If this understanding and awareness is focused upon real-world problems then students will encounter some computational tasks that they can understand but cannot solve. This is a good situation, and calculator usage here is desirable.

At the intermediate level (grades 4-6) it is useful to have classroom sets of calculators. Students can receive instruction in their use and begin to develop the skills necessary to have a calculator be a useful tool. Some decreased emphasis upon paper and pencil calculation can occur. This can be replaced by increased emphasis upon mental arithmetic (both exact and approximate) and upon problem solving. There can be increased emphasis upon areas of mathematics such as geometry, logic, and statistics.

By the time students finish grade school they can have good skills in using a calculator to perform the four basic functions. Also, they can learn to use the memory features of a 4-key memory system, and hence to deal with fractions and more complex calculations. This will require some classroom instructional time and a lot of practice. It requires a higher level of calculator knowledge than most elementary teachers currently possess. The issue of how much students should use calculators is still not settled. Many math educators suggest that virtually unlimited calculator usage in the intermediate grades and higher is both acceptable and desirable. This would cause a significant change in the curriculum, and they feel this would be a change for the better.

Other math educators are more cautious or conservative. They are quick to point out that the secondary schools and national testing services must first accept calculators, so that students will be allowed to use them at all educational levels and in all testing situations. They also note that many parents object to their children using calculators, and that we do not know the long-term effects of substantial calculator usage. It now seems likely that calculator usage will become more and more acceptable throughout all of education, but that the rate of acceptance will be slow.

To summarize, calculators should have the following effects upon the elementary school curriculum:

1. Students should be expected to develop better exact and approximate mental arithmetic skills.
2. Problem solving should be stressed at all levels, resulting in better problem solving skills.
3. There should be a decreased emphasis upon paper and pencil calculation.
4. Students should learn to use calculators, developing a high level of skill and accuracy, and learn to use the memory features.

We have previously mentioned that there is no fine dividing line between calculators and computers. Handheld computers first became commercially available in the latter part of 1980. Calculator-like in appearance, these computers are programmable in BASIC and have many of the features of larger computers. Students can learn a substantial amount about computers by studying and using handheld calculators and handheld computers. Calculators and computers

employ the same types of electronic circuitry and the same types of internal logic. Calculator arithmetic and computer arithmetic (based upon their machine number systems) are similar. The general ideas of problem solving using calculators are similar to those of problem solving using computers. All of this is an added motivation for the integration of calculator usage throughout the curriculum.

Calculators are easy to learn how to use at a superficial level. But it takes a significant amount of effort to learn to use the memory features of a calculator and the functions on a multi-function calculator. The calculator number system is different than the real number system, and hence there are peculiarities about calculator arithmetic that a teacher should understand. All of this is intended to suggest that if a teacher is to make serious use of calculators in the classroom there will need to be substantial learning on the part of both students and the teacher.

## What do Elementary School Teachers Need to Know About Computers?

Elementary school teachers need to be calculator and computer literate. They need to know how to use calculators and computers, and the expected results of using these machines in schools. An awareness level of computer literacy can come from reading this booklet. This literacy level can be expanded through hands on computer experience and through using calculators and computers with students. For teachers who are seriously interested in computers, however, a substantial program of study at a college or university is likely to be necessary.

Graph by Percy Franklin omitted to decrease Web retrieval time needed for this document.

Most people understand that one can begin studying a discipline such as mathematics, literature, writing, or science in elementary school and continue to study it up through a college degree or even a Ph.D. Suppose you had never encountered mathematics (arithmetic) before, and then someone came to you and said that you needed to be mathematics literate. It is obvious that reading a short booklet on mathematics would not give you a level of mathematics literacy adequate to being an elementary school teacher.

Computer Science (often called Computer and Information Science) is a new discipline. The first college degree programs in this discipline were started in the early 1960's. But this discipline already has a depth and breadth comparable to the other major academic fields of study. There are now hundreds of research journals in computer science; more students are getting bachelor's degrees in computer science than in mathematics.

This short booklet is designed to help you begin to acquire a minimum level of computer literacy. A few hours of hands-on computer experience and the reading of this booklet can make a substantial contribution to your total knowledge of computers, especially as they are applied to education. But you should realize that you have only scratched the surface. You could spend a lifetime studying computer science and computers in education, and still not learn all that is currently known in these fields

Here are four ways to increase your knowledge of computer science and of computers in education.

1. Be aware of computers in your everyday reading, television watching, etc. Newspapers, magazines, news broadcasts, television science specials, your education journals, and so on all carry material about computers. Since you now have some solid knowledge about computers it isn't too hard to add to it. Be especially aware of ads for computer-related products. They give a good indication of the current state of the art in hardware and software.
2. Talk about computers and calculators with your friends and fellow teachers, and with your students. Read the next section of this booklet, which contains a number of classroom activities, and begin to try some of these with your students. Learn by doing,

and let other people help you learn. Some of your students may know more about computers than you do. You and your class can learn from these students.

3. Take a formal computer science course. Most likely you can find a computer programming course at a nearby college or university. Maybe you can get your school system to arrange a workshop or an inservice course. If you are serious about learning more about computers than eventually you will need this formal instruction.
4. Subscribe to, and read, some computer-oriented publications. A list of some periodicals is given in the Brief Guide to Periodical Literature section of this booklet. By all means subscribe to *The Computing Teacher*, as it is specifically designed for teachers.

There are many aspects of computer science that have been mentioned only briefly or not at all in this booklet. Some of the subfields where one might concentrate their studies include artificial intelligence, business data processing, computer graphics, information retrieval, numerical analysis, programming languages, simulation, and theory of computation. One can also approach the field of computer science from an electrical engineering point of view. The design of chips and of computer circuitry, and interfacing computers with other equipment, are of major concern to electrical engineers.

As you think about taking a formal course in computer science you may wonder if you have enough mathematics background. The typical college level introductory computer science course makes use of some materials from second year high school algebra. If your mathematics background is not up to this level you may need to do some extra work on math to get through the course. But computer science and mathematics are two distinct disciplines. You do not need to be a mathematical wizard to learn about computers. Every teacher is capable of acquiring a working knowledge of computers in education.

## **Elementary School Computer-Related Activities**

This section contains a variety of computer-related activities that can be used in an elementary school or in a teacher training setting. Some of the activities are specifically designed for teacher training, while others are designed to help children learn about calculators and computers. Some of the calculator and computer activities can be done without access to equipment, and require very little teacher knowledge. Still others require some access to calculator or computer equipment, and a corresponding increase in knowledge on your part. References [1,2] are excellent sources of information. This section is an expanded version of reference [3], and summarizes some of the key ideas given earlier in this booklet.

Computers are affecting the elementary school classroom in three major ways:

1. Computers are the basis for an important new discipline, computer science. The computer is a versatile and valuable aid to problem solving in almost every academic area. Eventually its use will be considered to be one of the "basics" of a modern education; instruction in computer science will begin in the elementary school.
2. Computers are a new and versatile instructional medium. Computer assisted learning will eventually be commonplace in both the school and the home.
3. Computers affect what is taught and what it means to "know" something. We can see this even with such a simple computational device as a pocket calculator. A student can learn to calculate the square root of a number by use of a calculator, and the student can study the meaning and applications of square root. This is an alternative to spending the time necessary to learn how to calculate a square root using pencil and paper, and developing skill in using that algorithm.

## **The Psychological Barrier**

Every teacher has some knowledge about computers and is capable of increasing that knowledge. The fact that you are reading this material is a sign that you have an above average interest in learning more about computers.

If you are like most elementary school teachers, then so far computers have had little or no impact upon your classroom. Why is this? While it is easy to compile a long list of excuses, this is not particularly useful. You could decide right now, today, that computers will affect your class the next time it meets.

Such a decision may be frightening to you. The Thinking Activities (TAs) given in this section are designed to help you become aware of your apprehensions and fears. These activities can be role-played in a teacher training setting. Alternatively, you can work with them by yourself, as is suggested in the next paragraph.

Make yourself comfortable in an easy chair, on a couch, or on some cushions. Select one of the TAs and read it. Then close your eyes and think about the activity. Get in touch with your bodily reactions and your feelings. Spend a couple of minutes mentally exploring these feelings. Then open your eyes, relax, take a few deep breaths, and think over the experience. What did you learn about yourself?

**TA1.** Imagine yourself at a meeting of parents and faculty. A parent of one of your students asks the principal the following question: "I work with computers all the time, and I want my children to learn about computers. What are you doing to help students in this school to learn about computers?"

You are relieved that the question has not been directed at you, but then your principal turns to you and says, "Can you help us on this question?" Now you are on the spot!

**TA2.** Imagine yourself at a professional education meeting during a teacher inservice day. A person is demonstrating a microcomputer to a group of teachers. S/he is showing how easy it is to interact with a program that is in the machine's memory.

You happen to be near the front of the group when the demonstration leader asks for a volunteer. The request is for a person to tryout the program that has just been demonstrated. You think about volunteering.

**TA3.** Imagine yourself in front of your class tomorrow. One of your students asks: "My mother says that they just got a new computer where she works. She says it is a pretty smart machine. Are computers smarter than people?" How do you handle this question?

**TA4.** Imagine yourself at a staff meeting next week. A visitor from a university discusses calculators, and how students who are allowed to use calculators make significant gains on the problem solving sections of nationally standardized tests. Next your principal indicates that each teacher who wants to can have a classroom set of calculators for use during the remainder of the year. The principal turns to you and says, "Would you like to have a classroom set?" How do you respond?

## Computer Related Activities

Your mind is made up, you are ready to go, tomorrow you will do something related to computers in your classroom; but, what can you do?

It is not necessary to be a computer expert in order to help your students learn about computers. Indeed, it is not even necessary that you know more than your students, although it is highly likely that you do. What is necessary is a willingness to try and a willingness to learn.

The Computer-Related Activities (CRA) given in this section are designed to increase student awareness and knowledge about computers. Some of them are computer readiness activities, analogous to reading readiness. Others are designed to impart specific knowledge about the capabilities and limitations of computers.

**CRA1.** What do your students know about computers? Ask them! Have each student write a couple of sentences or a couple of paragraphs telling something they know about computers. Have several students read their reports to the class. You may be surprised and amused at the results. Students know about computers from their parents and siblings, from television and movies, and from comic books. Thus, much of what they "know" may indeed be fiction.

**CRA2.** How do machines help people, and what problems do they create? Build a unit around this question. Students can collect pictures of various types of machines. For each machine, indicate the problem it is designed to help solve. Also, the students should try to think of problems in our current society that have been created or contributed to by the machine.

**CRA3.** Who uses computers? Have each student talk to their parents about this. More than half of all people now have jobs which relate to computer usage and/or in places where computers are an everyday tool. Have each student write a brief report on their findings. Another approach is to have students make a list of occupations, and then investigate how computers are affecting these occupations.

**CRA4.** One standard measure of a computer's capabilities is how many millions of instructions per second (MIPS) it can perform. A medium scale computer, currently costing about a quarter of a million dollars, may be rated at one MIPS. The fastest computers currently available, costing more than \$10 million each, are rated at 50 to 100 MIPS. An instruction may involve adding or multiplying two decimal numbers, comparing two quantities to see if they are equal, or similar things.

There are many things you can do to help your students understand MIPS. A few are listed below.

- a. Select an arithmetic facts drill sheet appropriate to the students you teach. Time your students as they do these drill questions. Help each student to determine the number of questions s/he can answer per minute. Based upon this data help each student to determine how long it would take to answer a million of these questions.
- b. A computer rated at one MIPS can examine and do some processing on a million characters (letters, digits, punctuation marks) in a second. How long does it take a student to read a million characters? How many books is this? This question involves timing students as they read a couple of pages, counting the number of characters on these pages, estimating the number of characters in a book, etc. For very young students, the teacher will need to give very detailed directions and carry out most of the

computations. Note that a calculator is a useful aid in solving such a problem. A very thick adult novel, perhaps 500 pages long, is apt to contain about a million characters. Find such a book and show it to your class.

- c. How long does it take to count to a million by 1's? A computer rated at one MIPS can do it in a second. As your students struggle with this question, you can point out things like: "You can count 1, 2, 3, 4, much faster than 100001, 100002, 100003, etc."

**CRA5.** Computer scientists define the word procedure as follows: A procedure is a step-by-step set of instructions that can be mechanically interpreted and carried out by some agent. It is designed to solve a specified type of problem. Computer scientists are particularly interested in procedures where the agent is a computer or a person working with a computer. Many of the things we teach students are merely procedures where the agent is a student, perhaps assisted by pencil and paper or a book. Algorithms from arithmetic, and how to find a word in a dictionary, are examples. The activities given below are designed to acquaint students with the concept of a procedure.

- a. Have each student draw a map showing how to get from the classroom to the lunchroom (or some other place you designate). The map is to give explicit directions, easily followed by other students.
- b. Divide the class into teams of two and provide each team with a dictionary. Give each team a word to look up. One member of the team holds and uses the dictionary. The second member of the team gives directions to the dictionary holder, but is not allowed to see the pages of the dictionary. The dictionary holder is only allowed to follow the directions being given, and to answer questions upon request. After a word has been found, switch roles and try a different word. The same activity can be used with looking up a name and phone number in a telephone directory.
- c. Select some pencil and paper arithmetic exercises appropriate to your students levels. Divide students into pairs. Follow the same ideas as in (b) above. One student is to carry out an algorithm that is being specified by a second student. The student with paper and pencil is to mechanically, in a non-thinking fashion, precisely follow the instructions being given.
- d. Prepare a set of 25 to 50 cards each containing a different number on one side and a different word (or person's name) on the other. If resources permit it is desirable to have a set of cards for each student. First, have each student arrange his/her cards in numerical order, with the lowest number first. Then, have students write down (or explain to a partner) how to numerically order a set of cards. Then repeat for alphabetically ordering the cards.

This activity is particularly interesting because it illustrates that people can carry out a task, such as numerically ordering a set of cards, though they may not be able to verbalize or express in writing the details of what they are doing. If a computer is to accomplish such a task, the details of every step of the procedure must be explicitly given.

- e. Divide students into pairs. Designate one student in each pair to be the ROBOT. The other student commands the ROBOT with instructions such as TURN RIGHT, TURN LEFT, STOP, GO FORWARD 6 STEPS, and so on. Initially, students can practice with moving their robots to different places in the room.



After each student has developed skill in directing and being a robot you can increase the difficulty of the task. One way is to require that the instructions be written out in advance. Another way is to give the ROBOT more capabilities. For example, EXTEND RIGHT ARM FORWARD. IF YOU TOUCH THE WALL, THEN STOP, OTHERWISE... That is, given the ROBOT the ability to test whether a certain condition is satisfied and to make a decision based upon the results. A ROBOT with decision-making capability can, following an appropriate program, accomplish very complex tasks.

- f. Students know many procedures, such as how to check out a book from a library, how to look up a number in a phone book, how to use a phone, how to get from one place to another via bus or subway, how to tie a shoe, and so on. Have each student make a list of procedures s/he knows, in each case telling what problem is solved.
- g. What are different ways to represent procedures? A musical score represents a procedure to produce music. A carpenter's plans can be a procedure to build a house. A flowchart can be used to represent a mathematical procedure. A recipe is a cook's procedure. Have students suggest as many ways as possible for representing procedures.

## Calculator-Based Activities

A handheld calculator has a central processing unit, memory, and circuitry much like a full-scale computer. There is no abrupt dividing line between calculators and computers, and one can learn much about computers by studying calculators.

Almost every elementary school has a few calculators, and many have a classroom set. If none are available in your school have your students bring them from home. Most homes in the United States now have a calculator. Thus, you should be able to accumulate enough machines to try some of the following Calculator-Based Activities (CBA).

**CRA 1.** Students need to learn to turn on a calculator, key in a calculation, clear an entry or the whole machine, and turn off the calculator. With most students, a minute or two of instruction will suffice.

You can give this instruction to the whole class, if you have a classroom set of similar calculators. If you have a modest number and/or a variety of machines, use peer instruction. Train one or two students and let them work one-on-one with other students. It is desirable for students to gain experience with a variety of machines.

**CRA2.** There are many modes of calculation, such as mental arithmetic, using pencil and paper, using math tables, and using a calculator. Which is best? It depends upon the situation and what task is to be accomplished.

- a. Select a drill sheet of simple number facts that students in your class have mastered. Give half the class calculators and run a speed and accuracy contest between the calculator group and the non'-calculator group. The calculator group is required to do each calculation on a calculator. You want students to learn that mental arithmetic is quicker and at least as accurate as a calculator on these types of calculations. After completing the experiment, switch the calculators between groups and repeat the experiment.

- b. Select a sheet of hard calculations, that are near the limits of your students pencil and paper skills. Repeat (a) above using these problems. You want students to learn that on certain types of calculations a machine is both faster and more accurate.
- c. Allow students to become familiar with other modes of calculation such as use of a table or use of an abacus. Then repeat experiments like (a) and (b) above.

**CRA3.** If your students are at the upper elementary level, they can learn to use a calculator with memory. Typically, such a machine has M+, M-, MR, and CM keys in addition to those on a simple four-function calculator. The extra calculator memory is useful when performing calculations such as  $7/12 - 3/17$  or  $(89.4 \times 62.8) - (16.7 \times 39.5)$ .

It is recommended that you study a book such as [1] before starting your students on such exercises. That book contains considerable information about the use of calculators in problem solving, and the relation between calculators and computers.

**CRA4.** Most calculators use decimal fractions in their calculations. Thus 1 divided by 3 is 0.3333333. Students can be given a decimal fraction and asked to find two integers whose quotient is equal to, or as close as possible to, the decimal fraction. Answers for 0.3333333 include 1 divided by 3, 2 divided by 6, 3 divided by 9, and -1 divided by -3.

You can make up problems for your students by working from an answer back to a problem. Thus you note 3 divided by 7 is 0.4285714, and you ask the students to find a fraction whose calculator decimal equivalent is 0.4285714.

## Computer Activities

With a computer available, one can teach using a computer or one can teach about the computer. The former is often known as computer assisted learning (CAL). The major emphasis in the latter may be to teach computer programming or computer science.

Students at almost every grade level can learn to program a computer provided that their instructor is sufficiently knowledgeable and that appropriate hardware and software are available. Currently, this is a very rare situation. The Computer Activities (CA) presented in this section are much more elementary. They are designed for teachers who have had a very modest amount of computer experience. A short workshop with an hour of hands-on experience is adequate. It is assumed that you have a microcomputer or a timeshared terminal for students to use.

**CA1.** Once a program has been loaded into a computer's primary storage, the actual use of it is simple. If the program is written in BASIC, for example, (which is the most widely used language on microcomputers) one need only type the word RUN, and then push the RETURN or ENTER key. After that, one interacts with the computer following the directions it provides. If the program has been appropriately designed even a preschool aged child can experience considerable success in this endeavor.

Select a game or other "fun" activity from a program library and load it into your computer's primary storage. Select a student, and show him/her how to run the program. Watch what the student does, and answer questions as necessary.

When the program finishes, have the student select another student. The student who has just run the program plays the role of teacher. You are available as an emergency backup, but likely

you won't be needed. Each student in turn selects another student, until every student has used the machine. This type of peer instruction is an excellent aid to learning and to confidence building.

**CA2.** The difficulty of fetching a program from secondary storage (tape or disk) into primary storage is roughly comparable to learning to use a TV set or a stereo set. Thus, with appropriate instruction and experience, even quite young students can master the process. A good approach is, as in CA1. Select a student and teach this student how to fetch a program from the computer library. Let this student teach the next student, and so on. You will want to monitor the whole process somewhat more carefully than CA1, since there are more things that can go wrong.

**CA3.** After students have completed CA2, have each student load and run two or three different programs. Each student is to write a brief report on what each program does. The report should include a discussion of which program they liked best, and why.

**CA4.** Let each student use a drill and practice program or a more sophisticated CAI program. Then have each student write a short report on whether they would rather be taught by a teacher or a computer.

## References

1. Moursund, David: *Calculators In The Classroom: With Applications for the Elementary and Middle School Teacher*. John Wiley & Sons, Inc., 1980.
2. Billings, Karen and Moursund, David: *Are You Computer Literate?* dilithium Press, 1979.
3. Moursund, David: "Elementary School Computer-Related Activities," *The Computing Teacher*. V7 N5 April-May, 1980, pg. 28-31.

## Brief Guide to Periodical Literature

The Association for Computing Machinery publishes Computing Reviews as well as a number of other periodicals. Computing Reviews contains brief comments and abstracts on computer-related books and on articles from about 300 periodicals in the computer field. Thus, there is an overwhelming abundance of literature in this field. A few of the periodicals are of particular interest to educators concerned with the instructional use of computers. Among these are:

1. Association for Computing Machinery, P.O. Box 12105, Church Station, New York, N.Y. 10249. (\$28 per year; members receive the Communications of the ACM, published 12 times per year; a large number of other publications are available at additional cost.)

Besides publishing many research papers and the Computing Reviews, the ACM sponsors nearly three-dozen Special Interest Groups, each with its own publication. Also, ACM has an Elementary and Secondary Schools Subcommittee that is actively engaged in working on the problems of instructional use of computers at the pre-college level.

2. Association for the Development of Computer-Based Instructional Systems, Computer Center, Western Washington, Bellingham, WA 98225. (Membership is \$30 Journal of Computer-Based Instruction published 4 times per year and the ADCIS News published 6 times per year.)

The ADCIS publications emphasize teaching using computers. The organization has a number of special interest groups, including one aimed at the pre-college and junior college levels.

3. Association for Educational Data Systems, 1201 Washington, D.C. 20036. (\$30 per year; member receive the AEDS Journal, the AEDS Monitor, and the AEDS Bulletin, each published 4 times per year).

The Association for Educational Data Systems publications are designed for both school administrators and teachers who are interested in the instructional and the administrative use of computers. AEDS is a national professional organization with a number of active statewide affiliates.

4. Computerworld, 375 Cochituate Road, Rte. 30, 01701. (\$30 per year; published weekly.)

This newspaper-format publication has a circulation of about 100,000. It carries general news about all aspects of the computer field. Each issue contains one or more feature articles, and many of these are of interest to educators.

5. Creative Computing, P.O. Box 780-M, Morristown, N.J. 07960. (\$15 for 12 issues; published 12 times per year.)

Written for owners and users of computers, especially microcomputers. Contains a large amount of material of interest to students and educators, and considerable software. Creative Computing also produces and sells software.

6. Recreational Computing, People's Computing Company, 1263 El Camino Real, Box I, Menlo Park, CA 94025. (\$10 for 6 issues; published 6 times per year.)

Recreational Computing is designed for people who want to have fun with computers. The publication is strongly directed towards education, and contains a substantial amount of software as well as problems useful in an educational setting.

7. Technological Horizons in Education Journal, P.O. Box 992, Acton, MA 01720. (Free to certain qualified educators, \$9.50 per year for others; 6 issues per year.)

T. H. E. Journal contains articles on educational uses of computers as well as articles on other technological aids to education. The material is aimed at both teachers and administrators.

8. The Computing Teacher, c/o Computing Center, Eastern Oregon State College, La Grande, Oregon 97850. (\$10 for 7 issues; published 7 times per year in 1980-81, and 9 times per year in 1981-82.)

*The Computing Teacher* is designed for elementary school and secondary school teachers interested in the instructional use of computers. It contains material of immediate classroom use to teachers as well as material of a more philosophical or theoretical nature. TCT is published by the International Council for Computers in Education, a professional organization whose goal is to further the field of instructional use computers.

The publications listed above are a representative cross section of what is available. There are several hundred other periodicals that contain a substantial amount of material or an occasional article on instructional use of computers at the pre-college level. The discipline-oriented professional educational journals, such as those published for math or for science teachers, provide a good example of this. It is also recommended that one contact the Minnesota Educational Computing Consortium, 2520 Broadway Drive, St. Paul, MN 55113 and get on the mailing list for their newsletter. Minnesota is currently the leading state in the U.S. in terms of instructional use of computers at the precollege level.

## Glossary

**Access time.** The amount of time required to gain access to a specified piece or type of information. If the information is a memorized fact the access time may be less than a second. If access is from a reference book the time needed may be a half-minute up to several minutes. If access is from a large library the time necessary may be many minutes or an hour or more. Very large amounts of information can be stored in a computerized information retrieval system. Access to a small amount of information from a computerized information retrieval system may take a small fraction of a second. Access to a large amount of information may take a few seconds.

**Algorithm.** A finite, step by step set of directions guaranteed to solve a specified type of problem. Grade school students learn algorithms for addition, subtraction, multiplication, and division of multi-digit whole numbers. They also learn algorithms for looking up a word in a dictionary and for alphabetizing a list of words. A computer can carry out the steps in many different types of algorithms. Thus the study of computers and the study of algorithms are closely related

**Artificial intelligence (AI).** How smart can a machine be? Artificial intelligence is the branch of computer science that studies this question. Computers can play games such as checkers and chess. They can carry on a conversation in English via computer terminal, aid in foreign language translation, and carry out some of the tasks that a teacher currently performs to help students learn. Education is faced by the problem of deciding what students should learn to do mentally, what they should learn to do using pencil and paper, and what they should learn to do using other aids such as a computer or a calculator. Progress in AI continually extends the capabilities of computers, and thus complicates the problem.

**BASIC.** Beginners All-purpose Symbolic Instruction Code. The most widely used computer programming language, originally designed for use by college students. BASIC is available on most inexpensive computers and is widely taught and use in secondary schools. While the language is sometimes taught to grade school students, there are other languages that are more suitable for use by children of this age level. See LOGO. .

**Binary digit.** One of the symbols 0 or 1. The binary number system uses just these two digits to represent numbers. Since numbers and other quantities inside a computer are coded using a binary code it is often felt that it is necessary to understand binary arithmetic in order to understand computers. This is not correct, and the existence of computers is not a good justification for trying to teach binary arithmetic to grade school students. Most adults who make use of computers on their jobs do not understand binary arithmetic.

**Bug.** An error, especially an error in a computer program. Detecting and correcting such errors is one of the key aspects of computer programming. Grade school students can learn to develop detailed step by step sets of directions designed to accomplish specified tasks. They can learn to detect and correct bugs in their sets of directions.

**Calculator.** A device designed to do arithmetic calculations. A simple, hand-held calculator can carry out the functions of addition, subtraction, multiplication, and division. A more expensive calculator will have many more built-in functions, such as square root, reciprocal, and functions

from advanced mathematics. A still more expensive calculator may be programmable, able to automatically follow a detailed step-by-step set of directions. The simple four-function calculator is an excellent topic of instruction and aid to learning mathematics at the elementary school level.

Cathode ray tube (CRT). The picture tube of a television set, and the display screen of many microcomputers. A widely used type of computer terminal consists of a CRT with a typewriter-style keyboard.

Central processing unit (CPU). The part of the computer hardware that takes instructions from computer memory, figures out what operations the instructions specify, and then carries out the instructions. The CPU of a medium scale modern computer system is able to process several million instructions per second.

Character. A letter, digit, punctuation mark, or other symbol from a specified symbol set. A computer is designed to store and work with characters. The size of a computer's memory is usually stated as the number of characters it can store. See K. Also, note that computer scientists often use the word byte in place of the word character.

Chip. A large scale integrated circuit, containing electronic circuitry equivalent to thousands of transistors, resistors, and other components. A single chip, less than a centimeter on a side, may contain almost all of the circuitry for a calculator. A small handful of chips may contain most of the circuitry for a complete computer.

Computer. A device for the input, storage, manipulation, and output of characters. It can function automatically and very rapidly, following a detailed set of directions in a program stored in its memory.

Computer assisted learning (CAL). The use of a computer in any aspect of the teaching/learning process.

Computer literacy. A knowledge of the capabilities, limitations, applications, and possible effects of computers. Two levels of computer literacy are often discussed. The lower level is an awareness knowledge. The higher level is a functional or working knowledge. Elementary school education can help create an awareness level of computer literacy and can lay foundations upon which students will develop a working knowledge of computers.

Debug. To remove the bugs (errors) from a computer program or other set of directions.

Disk. A storage device consisting of a flat circular plate coated with magnetic oxide, the same type of material used to coat magnetic tape. The disk may be made of flexible plastic, and therefore be called a 'floppy' disk. Disks can store large numbers of characters, providing rapid and inexpensive access to very large amounts of data. A floppy disk may store 100 to 150 K characters, while a hard disk pack may store 300 million characters or more.

Flowchart. A diagram consisting of various shapes of boxes, containing written sets of directions and connected by arrows, specifying a set of directions.

Hardware. A computer system consists of both physical machinery, called hardware, and computer programs called software. The five main hardware components of a computer are input units, primary storage, central processing unit, secondary storage, and output units. For an inexpensive microcomputer system the input and output units will be combined into a

typewriter-style keyboard terminal, and secondary storage may be via an inexpensive cassette tape recorder.

**Information retrieval (IR).** The branch of computer science that deals with the storage and retrieval of large amounts of information. The collection of information that can be accessed is often called a data bank. A large data bank may contain as much information as a large library.

**K.** A measure of storage capacity.  $K = 2$  raised to the 10th power, which is 1024. The primary storage of a computer is often stated as a number of K characters storage, such as 48K characters. A floppy disk, used for secondary storage on a microcomputer system, may have a storage capacity of 100 to 150K characters.

**Keyboard terminal.** A computer terminal with a typewriter-style keyboard, used to communicate with a computer. A keyboard terminal usually has a built-in CRT display or printing mechanism.

**LOGO.** A computer programming language developed by Seymour Papert at Massachusetts Institute of Technology, especially designed for use by grade school students.

**Memory.** A computer's storage facility. Generally it consists of primary storage, for very rapid access to a modest amount of data, and secondary storage, for less rapid access to larger amounts of data. **Microcomputer.** A computer whose central processing unit (the part of the machine that can automatically carry out the instructions in a program) consists of a single chip or a small number of chips. There are now many brands of microcomputers on the market, some costing under \$500 for a complete computer system. Because of this low price microcomputers are becoming common in homes and in elementary schools, and are now readily available in most secondary schools and in higher education.

**Microsecond.** A millionth of a second. A modern computer can access a character from primary storage or carry out a simple instruction such as the addition of two numbers in less than a microsecond.

**Nanosecond.** A billionth of a second. The most expensive computers now being manufactured can carry out an instruction in about ten nanoseconds. That is, such a machine can execute 100 million instructions in one second!

**PILOT.** A programming language especially designed for use by people wanting to write CAI materials. It is sometimes used as a programming language to be taught to elementary school students.

**Problem.** A problem consists of a given initial situation, a desired final situation, and a set of restrictions or rules about the types of steps or operations one can use in moving from the given to the goal. Each academic discipline has its own types of problems and methods of attacking these problems. Thus problem solving is one of the central and unifying themes of all of education.

**Program.** A detailed set of directions written in a form 'understandable' by a computer—that is, in a form so that a computer can automatically carry out the directions.

**Software.** A computer system consists of both physical machinery, called hardware, and computer programs, called software. Both are necessary if the system is to perform a useful function. One type of software is the language translators, that allow programmers to use languages such as BASIC, COBOL, LOGO, PASCAL, and PILOT. These programs translate from the aforementioned languages into the machine languages of specific machines. A computing



center often maintains a large library of programs designed to solve a wide variety of problems. Such a software library is an essential tool to most people who use computers on their jobs.

*Timesharing.* A method of computer usage, or type of computer system, in which several people can simultaneously use the system. The users gain access to the computer system via terminals, and the computer system shares its resources among the users.

*Videodisc.* A flat circular plate that can store television programs. Certain types of videodisc systems can be hooked to a microcomputer and allow access to single frames, slow motion forward or backwards, regular speed forward and backwards, etc. This is an exciting and excellent aid to CAI hardware.

*Word processing.* A computerized typewriter is called a word processing system. It can be used to store and edit typed material. It can be used to rearrange sentences, paragraphs, and larger sections. A word processing system may even include a built-in dictionary that can be used to automatically check for misspellings.