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ABSTRACT

In three parts, this booklet provides elementary teachers with definitions of essential computer terminology and examines instructional uses of computers and computer-related activities. Terms defined are computer, interactive computing, computer hardware, computer software, and programming languages. Part 2 explores the main categories of the educational use of computers (administrative, instructional, and research), the impact of computers on the curriculum (stressing the importance of computers as problem-solving tools), computers as aids to instruction (including computer-augmented learning, computer-managed instruction, and computer-assisted instruction), computer literacy (stressing student awareness and specific instruction in precollege education), the role of calculators in elementary education, and the need for elementary school teachers to be calculator and computer literate. Part 3 contains a variety of computer-related activities that can be used in an elementary school or in a teacher training setting. The need for access to computer equipment and the degree of teacher knowledge vary according to the activity. The booklet includes an appendix with references, a glossary, and an 11-entry guide to periodical literature dealing with pre-college instructional uses of computers. (PB)

The author of this booklet, David Moursund, is President of the International Council for Computers in Education. He is a professor at the University of Oregon, holding appointments in the Department of Computer and Information Science and in the Department of Curriculum and Instruction. Dr. Moursund is the author or co-author of eight textbooks and has also authored a large number of articles dealing with educational uses of computers. He is Chairman of the Association for Computing Machinery's Elementary and Secondary Schools Subcommittee, and he is Editor-in-Chief of *The Computing Teacher*.

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TEACHER'S GUIDE TO COMPUTERS IN THE ELEMENTARY SCHOOL

(Second Printing, August 1981)
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(Fourth Printing, with revisions, October 1982)

PREFACE

Most elementary school teachers are people-oriented. They are vitally concerned with children, in helping children develop their potential 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 machines dehumanize education and replace teachers?

The answers to these questions are both yes and no. Much depends on the teacher, the student, the equipment and the instructional materials. The knowledge, attitude and skills of the teacher are apt to be the dominant factors.

Over the past ten years the price of both calculators and computers has declined rapidly, so that now good quality calculators cost under $10, and computers are beginning to appear in many homes. Calculator and computer usage is commonplace in many elementary 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. 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.

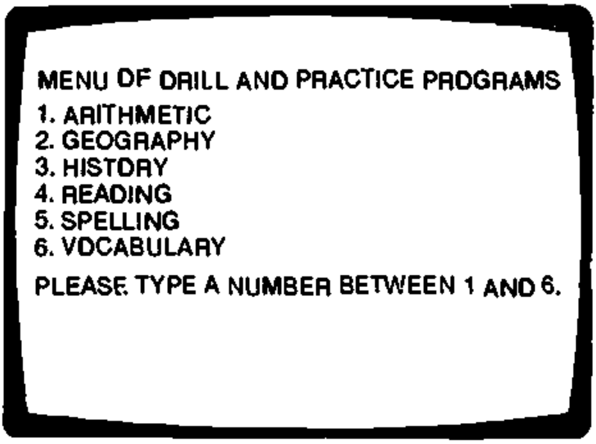
This booklet is organized as a sequence of questions and answers; each question is followed by a brief answer and by a longer, more detailed answer. The latter part of the booklet contains sample activities that can be used in an elementary school classroom or in a teacher training situation.

Included in the booklet are three appendices: *References*, a *Glossary* of frequently used terms in the computer education field and a *Brief Guide to Periodical Literature*, which lists periodicals of particular interest to educators.

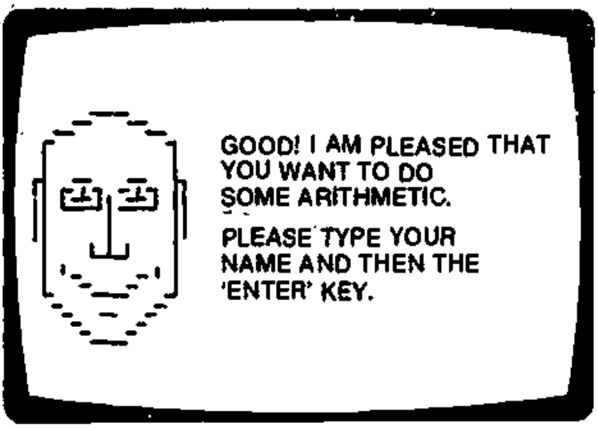
This booklet is written for preservice and inservice elementary school teachers. It is assumed that you have used a calculator; it is desirable that you also have had some hands-on experience with a computer. A half hour's interaction with a computer will add substantial meaning to what follows. Likely you can get this experience by visiting a local computer store or a local high school. The majority of high schools now make instructional use of computers.

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.

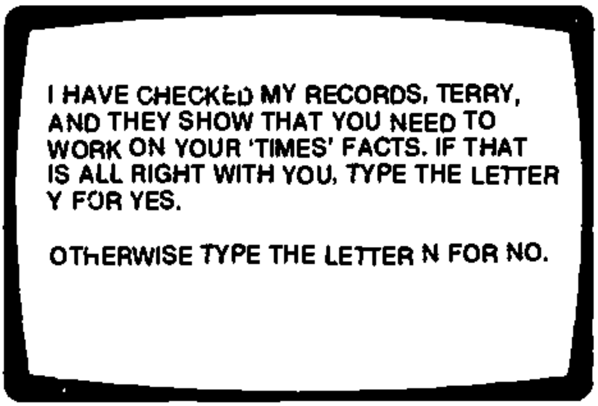
As you walk into the fourth grade classroom you see a student just sitting down in front of a TV set with a typewriter keyboard. You look over the student's shoulder at the TV display screen.



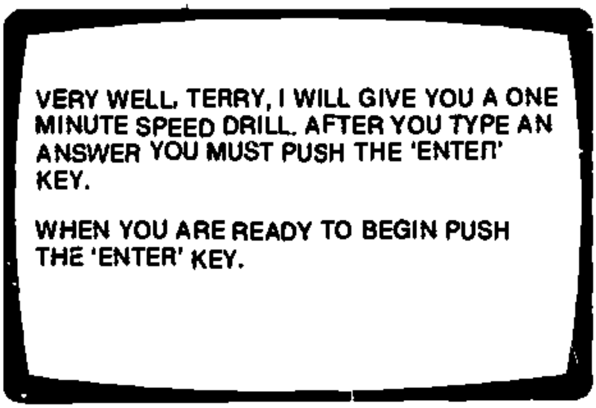
The student is obviously familiar with the computer equipment. Almost before you finish reading the directions s/he types the number 1. The printing on the TV screen disappears, but then is immediately replaced by more printing.



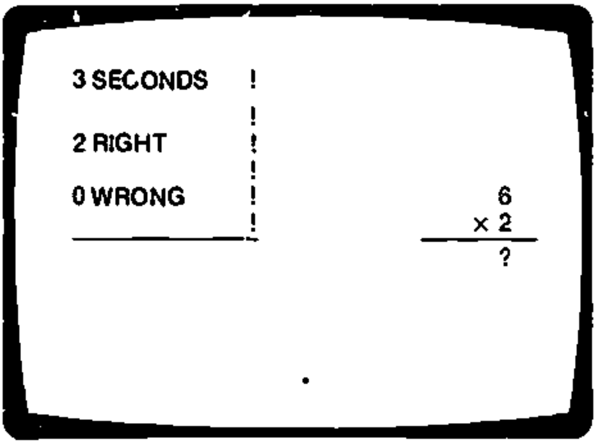
You watch as the student rather laboriously types in TERRY JOHNSON and pushes the ENTER key. After a couple of seconds the computer responds.



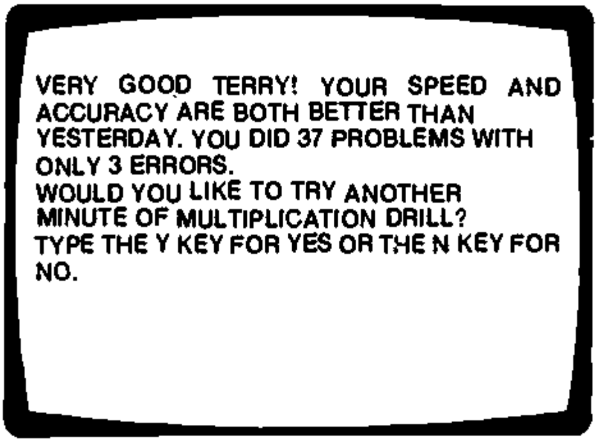
Terry, being an obedient and rather docile student, types the letter Y.



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.

MENU OF DRILL AND PRACTICE PROGRAMS

1. ARITHMETIC
2. GEOGRAPHY
3. HISTORY
4. READING
5. SPELLING
6. VOCABULARY

PLEASE TYPE A NUMBER BETWEEN 1 AND 6.

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 more easily affordable, 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. Indeed, a 1980 survey by Al Bork and Jack Chambers indicated that over 90% of school districts in the United States now make some use of computers. **Estimates and surveys done during 1982 suggest that over 100,000 microcomputers are now being used in education in the United States.**

Terry was interacting with the computer in a computer assisted learning mode. Computer assisted learning can help students to learn more, better and faster. But computers are having other impacts upon the elementary school.

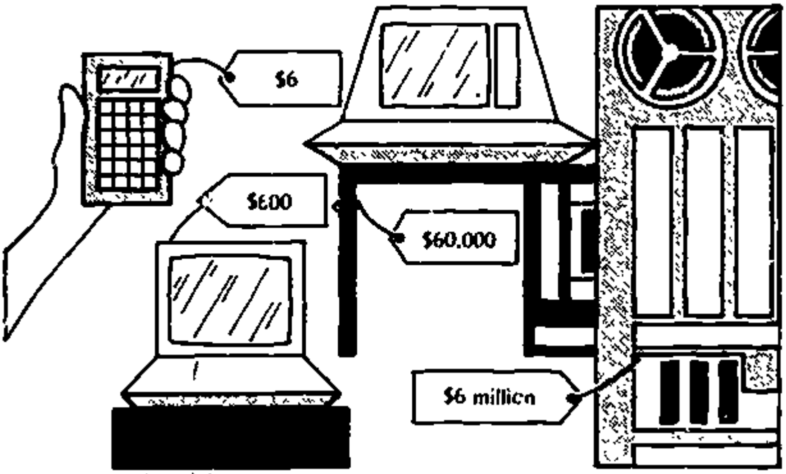
This booklet addresses questions such as, "How should the content of the elementary school curriculum change to reflect the capabilities of calculators and computers?" and, "What should students be learning about calculators and computers?"

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.

PART I — INTRODUCTION

What Is a Computer?

A computer is a machine designed for the input, storage, manipulation and output of symbols (digits, letters, punctuation). It can automatically follow a step-by-step set of directions (called a computer program) that has been stored in its memory. A computer is a general-purpose aid to problem solving in every academic discipline.



You are undoubtedly familiar with the hand-held calculator that can add, subtract, multiply and divide. This is an electronic calculating device because it runs on electricity and the calculation circuitry has no moving parts. It is a digital calculating device because it works with individual digits and with numbers represented by a sequence of digits. A hand-held 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. You now have a computer!

The main emphasis in this booklet is on 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. A hand-held calculator can be purchased for $6 or less, while the most expensive computer systems cost a million times this much, or more. The cheapest calculator and the most expensive computer do 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 an inexpensive calculator is no match for a computer in solving problems that make full use of a computer's capabilities.

We will study these capabilities and their educational implications. Some of the key ideas include the following:

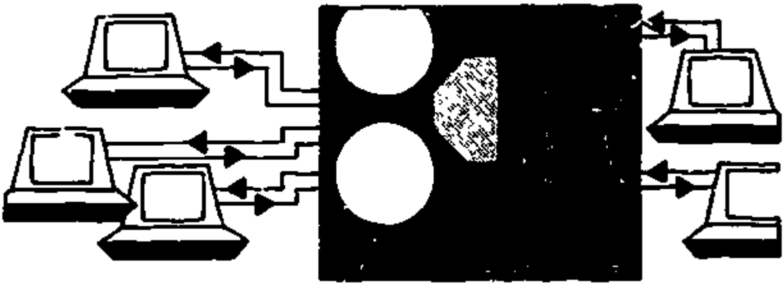
1. A computer can store a very large amount of data--useful in solving a wide variety of problems.
2. A computer can automatically follow a very long and complicated set of directions specifying how to solve a certain type of problem. Large libraries of such computer programs are now readily available.
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 and can solve a wide variety of problems.

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 general-purpose tools. **Eventually computers will gain a similar level of acceptance, and skill in their use will be exptected of all educated people.**

At one time computers were quite expensive, and it was unthinkable that school children would be allowed to use them. But now good quality microcomputers are available in the price range of $500 to $2,000. As of the end of 1981 more than a million microcomputers have been sold in the United States. They are now more commonly available in schools, and are increasingly a part of people's homes. **It is rapidly becoming unthinkable that school children not have access to computers.**

In mid-1982, one company was selling a hand-held computer, programmable in BASIC, for about $150. A number of companies now produce and sell hand-held or briefcase-sized computers, with prices ranging up to a thousand dollars or more. The trend towards cheaper, smaller, more capable microcomputers continues unabated.

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 1970s a new type of computer, called a microcomputer, was developed. It was designed to be used in an interactive mode but by only one person at a time. Now some microcomputers are so powerful that they can be used as a timeshared system by a number of simultaneous users.



The first general-purpose electronic digital computer became operational in December, 1945. It contained 18,000 vacuum tubes, filled up 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 took a week or more. Only a 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 first became common in 1960. 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 limited opportunity for a person to interact with the machine while it was actually solving a problem.

Two developments during the 1960s had a major impact on 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 process used to manufacture a single transistor could be used to produce a circuit containing dozens or even hundreds of transistors and other components. These were manufactured on a small piece of silicon called a *chip*. Progress in chip technology led to the building of complex circuits from a small handful of chips, plus appropriate connectors and power supply. Moreover, as these chips became increasingly inexpensive to manufacture, the price of computers decreased rapidly.

To begin the 1970s there were 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.

In the early 1970s smaller, less expensive computers, called minicomputers, rapidly gained acceptance. They began to be used in secondary schools, and became commonplace in higher education. Chip technology continued to progress, and the mid-1970s saw the introduction of *microcomputers*—machines whose electronic circuitry is based on 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; however, there are 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) are missing. Still, the microcomputer is revolutionizing the field of computers in precollege education. Its price is sufficiently low so that every school system can afford to provide some computer facilities.

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. Feedback may be provided by a teacher, other students or answer sheets. 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 aspect 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:

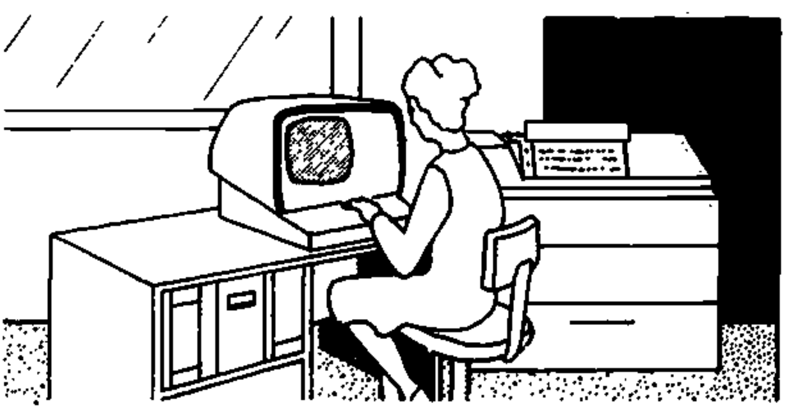
Input Unit—
Used to get information into the computer. The most common is an electric typewriter device called a keyboard terminal.

Output Unit—
Used to get information out of the computer. The most common is a television display screen, but typewriter-like printers are also widely used.

Memory—
Storage space for words and numbers, divided into primary and secondary storage.

- *Primary Storage—*
  Contains a program during execution, along with the data as it is being processed.
- *Secondary Storage—*
  A peripheral storage device that can store information in a form acceptable to the computer such as on magnetic tape or disk. Provides permanent, inexpensive storage of large libraries of computer programs and large quantities of data.

Central Processing Unit (CPU)—
Figures out the meaning of instructions in a program and carries them out very rapidly.



The least expensive microcomputer systems, costing under $500, have all five of the components listed above: input unit, output unit, primary storage, secondary storage and central processing unit (CPU). For an inexpensive microcomputer system the input unit is a typewriter-style keyboard, perhaps molded into a cabinet containing a television set. The output unit is a television set, perhaps specially modified to improve the quality of the display. Secondary storage may be a cassette tape recorder, using inexpensive cassette tapes. The central processing unit (CPU) 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 constructed out of chips.

More expensive microcomputer systems make use of *floppy disks* for the storage of data and programs. A floppy disk is a circular, flexible piece of plastic coated with iron oxide. A computer can access any piece of information on a floppy disk in under a second. Typically a floppy disk drive costs about $400 to $600. However, in 1981 one major computer manufacturer negotiated a special contract with the Minnesota Educational Computing Consortium. In this contract, the full cost of a microcomputer with one floppy disk and a black and white television display was $575.

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, 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 *bytes* (that is, letters, digits or punctuation marks). A large computer system will have a primary storage capacity several hundred times as large.

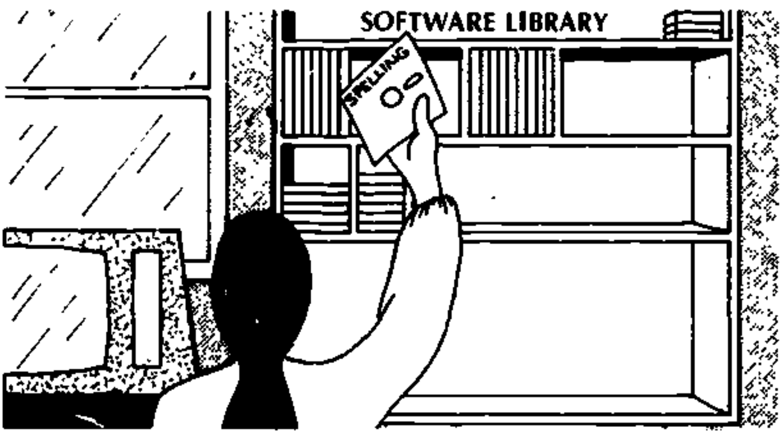
The large-scale computer system has a number of additional hardware features that help to improve its overall capability. For example, it will have a line printer that is many hundreds of times as fast as an electric typewriter. Printing speeds of thousands of words per minute are possible. It will have high quality, large capacity, magnetic tape units. It will make extensive use of hard disk storage units, which are flat, metal 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. A large-scale computer will have a variety of other input and output units such as an optical scanner, light pen, graphics pad, plotter and graphics terminal.

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 graphics tablet, 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. 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. Computer 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 videodisk is also an excellent secondary storage device for computers. A laser readout, computer controlled videodisc system can store 54,000 pictures on one disk—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 learning into homes and schools.

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. Many thousands of people make their living 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 by using a computer's secondary storage hardware. This software is then available for people to use—people who did not write the programs. You can use a computer without knowing how to write programs.



Computer programs are written in computer languages such as BASIC, COBOL, Logo, machine language, Pascal or PILOT. 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. Now, software is often the dominant cost. Of course the same software may be used by thousands of people, in which case its development 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 central processing unit (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 carries out certain simple manipulations of symbols.

If a computer is to solve a problem or help solve a problem then its central processing unit must be told precisely what it is to do. A human being must figure out how to solve the problem and how to tell the computer. 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. 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 field containing the problems. For example, a programmer may need to know a lot about business in order to write a program to solve a business problem.

A 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 in 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 important branch of computer science is called *Artificial Intelligence* (AI). Artificial Intelligence deals with how smart a computer can be—if it can do intelligent-like things. Computers car play complex games such as checkers or 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, AI may have a great impact upon education.

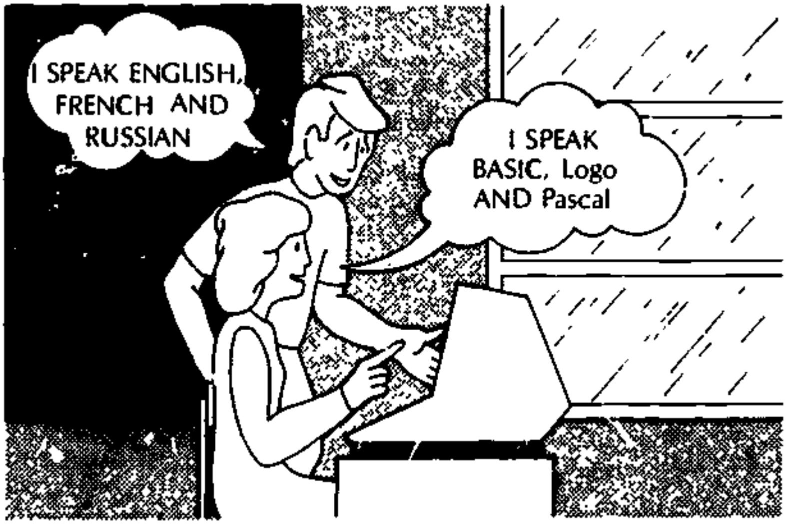
Computer libraries are now available that contain thousands of programs. Each program is designed to solve a particular type of problem. Some of the problems are quite complex—it might take a person months to learn to solve the problem without the aid of a machine. Some of the problems involve so much symbol manipulation (calculation) that the only practical method of solution is by use of computers. A modern, high-quality education demands that students learn to use computers as a general-purpose aid to problem solving.

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, there is a shortage of software designed to fit the wide variety of instructional needs that exist in elementary school education. However, in mid-1982 there were about 400 companies in North America producing educationally-oriented software. While these companies vary considerably in size, in total they are producing many thousands of new and/or revised pieces of software each year.

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 central processing unit (CPU) of a computer "understands" (that is, it 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, FORTRAN and Pascal, 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 these languages into machine language. A different translating program is needed for each programming language, and for almost every make or model of computer.



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 1950s, computer scientists 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 1960s 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 it is currently the most used language. If a language such as BASIC is to be used on a particular computer, there must be a translating program that 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 *          P = PERIMETER OF A RECTANGLE
170 REM *          W = WIDTH 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       END
```

When this program is run on an interactive computing system, it will print out directions to the user (lines 180-200), request values for the length and width of a rectangle (lines 210-240) and then compute

(lines 260-270) and output (lines 280-290) its area and perimeter. The user of the program does not need to remember the details of the formulas for area and perimeter. The program works equally well for simple numbers such as a 16 by 83 rectangle, and for more complicated numbers such as a 16.829 by 83.647 rectangle.

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 in order to have other languages available for use on the machine.

Programming languages are designed for precise communication between people and computers. Students at every grade level can learn to program if appropriate languages and hardware are available.

The language Logo was specifically designed to be suitable for elementary school students. Seymour Papert began developing this language at the Massachusetts Institute of Technology in the early 1970s and has continued to work with it ever since.

Most adults have difficulty believing that children can learn to program a computer. If learning to write programs is a difficult task for a college student, how can an elementary school student do it? A very good answer is provided by examining the analogy of learning a foreign language such as Spanish or Russian. It is hard work for an adult to learn a second language, but a child raised in a bilingual environment can easily become fluent in two languages.

Logo was designed to help create a learning environment, a place where students can learn by doing. Children in a Logo environment learn by doing and by interacting with other children. Adult guidance is sometimes necessary but, as with other forms of discovery learning, should be kept to a minimum. This requires that teachers be knowledgeable both in the programming language and in helping children to learn in a Logo environment.

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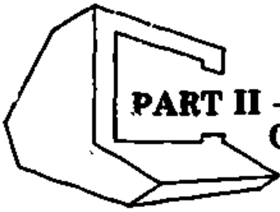
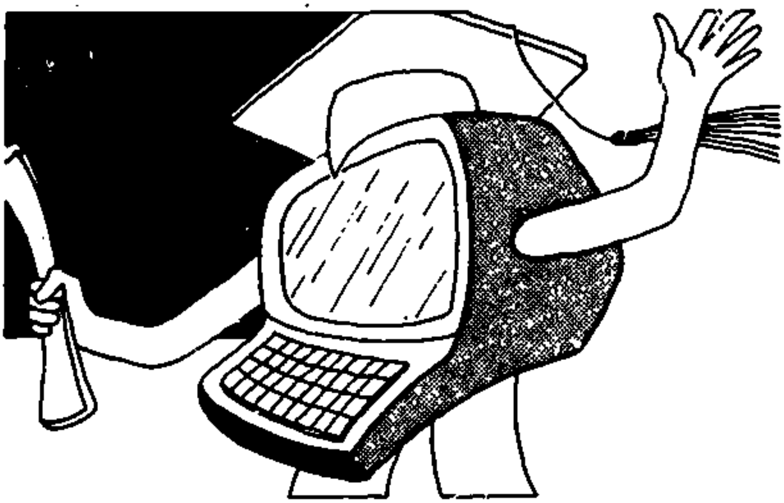


PART II — INSTRUCTIONAL USE OF COMPUTERS

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 3-4% of its entire budget on computing, with funds fairly evenly distributed among the three uses. The typical pre-college school system spends 1-2% of its budget for computing. Currently, administrative use far exceeds instructional use, and computers are used for relatively little research in school systems. Very few school districts in the United States currently spend even 1% of their budgets for instructional use of computers, although this type of usage is now growing quite rapidly.



We assume that you are most interested in instructional uses of computers, so most of the remainder of this booklet is devoted to various instructional aspects of computers. First, however, we discuss some administrative and research uses of computers in education.

In the United States the great majority of school systems make administrative use of computers, and this type of use continues to grow. 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, these tasks can be done better and more economically with computer assistance.

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 questions such as, "What if Bus #7 doesn't run today due to snow?" or "What if substitute teachers' salaries are raised 15%?" Because computers are such useful aids to school adminstrators, we can expect their use to increase rapidly in the years to come.

Computers are an essential tool to research in education. The United States government helps fund a number of educational research centers, called Educational Research Information Centers (ERIC), which subscribe to almost every educational journal and seek out literature on educational research. These centers hire people to write summaries and to index the articles. All of this information is put into a computerized information retrieval system for use by researchers.

For example, suppose you were interested in bilingual, multicultural education. 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 system.

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 comparisons

are made 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 analyses.

Both administrative and research uses 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 (noncomputerized) 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 instructional aspects of computers are discussed.

The remainder of this section discusses:

- Computers as they impact the general curriculum:
  The mere existence and widespread use of calculators and computers in the adult world requires modifications of the current curriculum.
- Computers as an aid to instruction:
  The goal is to help students learn more, better, faster.
- Computer literacy:
  What elementary students *should* be learning about computers if they are to be adequately prepared to cope with this aspect of their future education and life in our society.
- The role of calculators in the elementary school.

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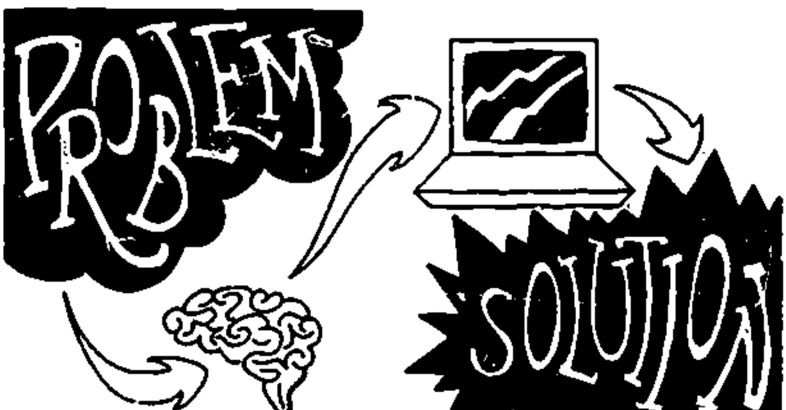
What Impact Should Computers Have on the Current Curriculum?

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 been developed—mainly to help solve adult types of problems. Elementary school educators must decide what role these machines will play: what students will learn to do mentally, what they will learn to do using simple tools such as pencil and paper, and what they will learn to do using more complex tools such as books, calculators and computers.



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

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

1. Understanding the problem.
   Here reading and listening are essential skills, and overall general education and common sense are important.

2. Figuring out and representing a plan of attack.
   Thinking, drawing on previous knowledge and writing are important.

3. Carrying out the plan.
   This may be a routine, rote task. Speed and accuracy are desirable, and perseverance and attention to detail are necessary.

4. Understanding the meaning of the results and checking to make sure they make sense.
   A thinking task, drawing on previous knowledge and on one's understanding of the problem.

Of these four steps, the easiest to teach and the easiest to test on standardized tests is Step 3. It is evident that this step is essential if a problem is to be solved, and 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! Moreover, adults now commonly use calculators and computers to help them in Step 3 situations.

We can gain insight into this 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 concept of these operations (what problem is being solved, why does one want to solve it) versus mastering the 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 improving students' mental arithmetic skills by increasing their understanding of the problems to be solved and by encouraging more experiences 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 and restructuring of the curriculum be done.

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 misspellings. The material is then 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 also significant. 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?

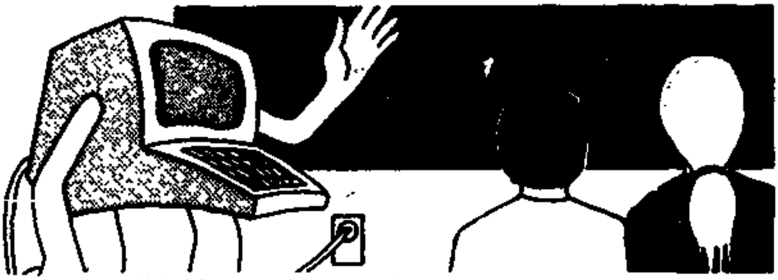
Still another interesting example is provided by a computer system attached to a music synthesizer. It may well be that many young children have the capability to compose music. But most children do not develop this talent, since they lack the skills to perform or represent the music they can create in their minds. An interactive computer system can help solve both of these problems. The use of such equipment in the elementary school curriculum could 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. We need to teach students to work with calculators and computers as well. Our overall curriculum needs to change, to reflect the important role that calculators and computers can play in problem solving. This means that we must decrease the emphasis on routine and rote skills of carrying out a plan to solve a problem, and instead to place increased emphasis on 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 essential tools—it is merely routine, rote paper and pencil manipulation that is decreasing in importance. Second, there is an increased need for accurate and rapid mental skills such as knowing the basic number facts and knowing how to spell and punctuate. In emphasizing these skills we are preparing students to work *with* the computer 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 available adequate and appropriate computer software and hardware. Since software and hardware can be quite expensive, the cost effectiveness of computer assisted learning should be questioned. However, the low cost of microcomputers now make computers a feasible aid to instruction.



The overall field of teaching and learning using computers is called computer assisted learning. Research in this field began in the late 1950s. A few massive federally-funded projects and many hundreds of smaller projects are reported 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 1960s. These are now used throughout the United States, distributed by the Computer Curriculum Corporation started by Suppes. A major drawback to extensive use of computer assisted learning has been its high cost. However, computer costs per hour of student usage have declined sharply since microcomputers began to be mass produced. Computers are now a cost-effective aid to instruction in a variety of situations.

Because, until the advent of microcomputers, computer assisted learning was too expensive for widespread implementation in ordinary public schools and the home, the great majority of computer assisted learning has been in medical schools, armed services education and in remedial education, where the cost of traditional education is high. Microcomputers have allowed two major changes.

First, they have reduced the cost of the hardware needed by a significant factor. Second, they have broadened the potential audience, as hundreds of thousands of microcomputers have now been sold. This allows the cost of software development to be spread among a larger number of users and makes the commercial development of computer assisted learning materials economically feasible. As computer costs continue to decline and better materials are developed, we can expect computer assisted learning to play an increasing role in all of education.

Computer assisted learning is often broken down into three parts, only two of which are apt to occur in an elementary school setting:

Computer Augmented Learning (CAL) is the easiest, quickest and probably the least expensive instructional use of computers to implement. With CAL, students write programs and/or make use of computer library programs to help solve the types of problems that arise in various academic studies. Large libraries of such programs have been developed for use by people in the real world, people who need to solve on-the-job problems, and such software is readily available. Both teachers and students can learn to use CAL programs with a minimum of training. Computer Augmented Learning is quite common at the college level, and is beginning to appear in 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 (CMI) is the use of computers as an aid to accomplishing management aspects of teaching and learning. For example, a computer can be used to score multiple choice or true/false tests, perform an item analysis on the questions, 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. It does require 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. As it is developed, it will initially be keyed to traditional, nationally-marketed 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 inexpensive alternatives to this such as flashcards, students drilling each other and hand-held 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 or her learning rate. At the most sophisticated level there exist a few 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 or running a business. Many of these simulations are quite realistic; interacting with them is exciting and results in substantial learning.

Computers are proving to be especially useful in helping handicapped children. Physically handicapped children use computerized systems to aid in communication and in gaining access to information. Voice input and voice output devices are of growing importance. Learning-disabled children benefit from computer assisted instruction. The computer as a patient, individualized tutor is quite successful with these students.

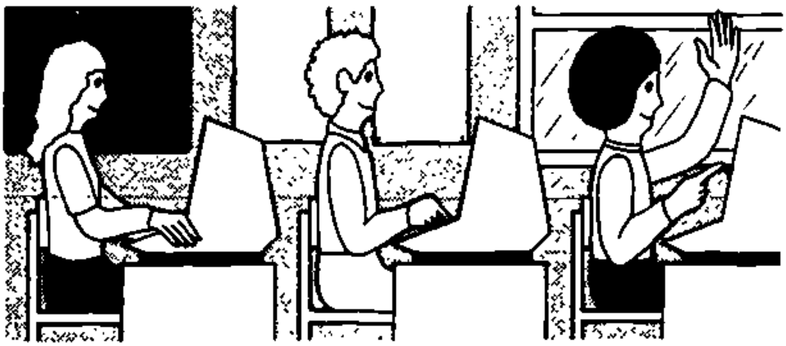
Computer assisted learning is a direct challenge to teachers and to much of traditional education. As more and more good materials are developed and are proven effective in widespread use, the current role of teachers in education may change. Students will be able to have inexpensive, patient, interactive, personalized tutors to use at home, in public libraries and in school settings. Al Bork, one of the leading proponents of computer assisted learning 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 will change teaching. 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 computer assisted learning can help fill some of these roles, it makes little or no contribution to others. Children need loving, caring, feeling teachers. Computers can give teachers more time to use these human capabilities.

Leaders in the computers-in-education field agree that all 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 computer knowledge are important in precollege education: an *awareness* level and a working-tool, or *functional* level. An awareness level can begin to be developed in elementary school and can be integrated into each subject the student studies. A functional level requires specific instruction in the use of a computer, including 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 addressed primarily at the post-high school level, although a few high schools do offer some professional level training.



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. However, 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 were 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 therefore 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 accompanied by a continued, rapid decrease in the price of computer hardware. As computers have increasingly 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 focuses on 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 250-300 students in grades 1-6. The school has three microcomputers which are housed in the library media center, along with a library of software appropriate to the needs of students. The media specialist knows the rudiments [illegible]ng the microcomputers, and who to contact if maintenance o[illegible]pair 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 will not have a significant impact upon a student's overall instructional program. That is not enough computer access for a significant computer assisted learning program. But the following goals could be accomplished:

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

The overall result of this program is that each student will learn to use a computer in a wide variety of ways and will likely enjoy the overall process. Part III of this booklet contains a number of sample activities that can be carried out in a classroom. Along with appropriate movies or other multi-media aids, these activities will contribute significantly to student awareness of computers.

The schedule of microcomputer usage listed above is based upon a 5-hour day, 180 days per year. If students have access to computers before and after school, during lunch time and on evenings and 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. Some students might learn to program in Logo or BASIC.

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 computers are available, then computer assisted learning 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 computer assisted learning should be used, a considerably higher level of computer access will be necessary; typically, a specified group of students will have everyday access to a computer. For example, it is common to have students drill on arithmetic or on language arts skills for 10-15 minutes each day. When the computer is not being used for these purposes it can be used to allow increased computer access by all students in the school.

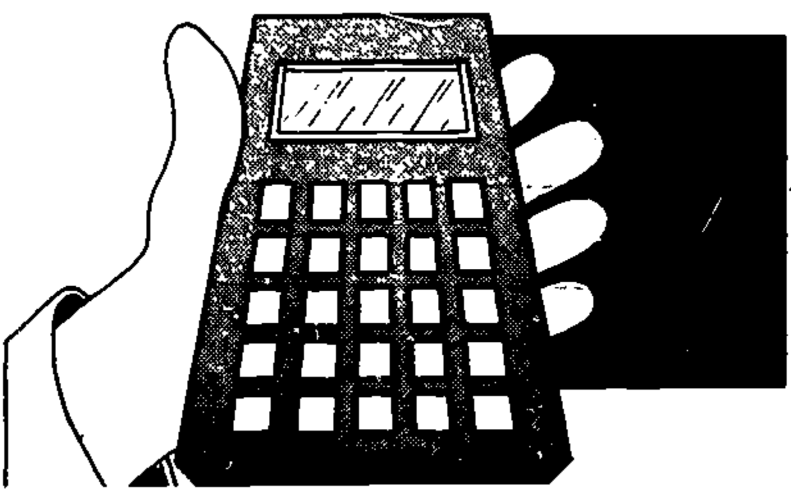
There are now some people who advocate that all elementary school students learn to use the Logo programming language and learn to use a word processing system. Research has demonstrated that this is possible if appropriate equipment and instruction are available. Currently, few elementary schools can afford adequate computer facilities for this; moreover, few elementary teachers have an adequate knowledge of computers to handle such a learning environment. Thus, such a massive influx of computers into elementary school education is not likely to occur in the next few years.

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. Therefore, their greatest initial impact is on the math curriculum. The National Council of Teachers of Mathematics (NCTM) 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 then be spent on the "thinking" and other higher cognitive levels of activities needed in mathematical problem solving. This use of calculators 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.



Calculators and other electronic aids to mathematical calculation are now an everyday tool of most adults who need to do calculations. An estimated 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 $40.

Some major educational issues are:

1. What should students learn about calculators?
2. When should they learn it?
3. When and how 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 mathematical 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, their use can contribute substantially to it.

At the primary level (grades 1-3), calculators have only modest value. They are an additional math manipulative, an exploratory tool. Their occasional use can provide variety to the curriculum and can serve as an aid to learning materials 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 for the calculator to become a useful tool. Some decreased emphasis upon paper and pencil calculation can occur, with increased emphasis placed on mental arithmetic (both exact and approximate) and on problem solving. There can also be increased emphasis on areas of mathematics such as geometry, logic and statistics.

By the time students finish elementary school they will have developed good skills in using a calculator to perform the four basic functions. They can learn to use the memory features of a 4-key memory system and therefore can work 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 the virtually unlimited use of calculators 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 the use of calculators 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:

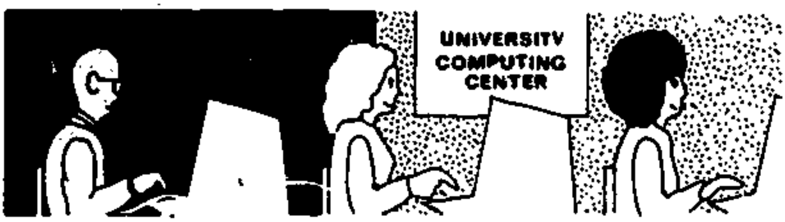
1. Students should be expected to develop better exact and approximate mental arithmetic skills.
2. Problem solving should be stressed at all levels, resulting in better problem-solving skills.
3. There should be a decreased emphasis upon paper and pencil calculation, especially for multidigit multiplication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

It was previously mentioned that there is no fine dividing line between calculators and computers. Hand-held 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 hand-held calculators and hand-held 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 to use at a superficial level. However, 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. Therefore, 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 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.



Educators 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 the level of 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 the level of mathematics literacy necessary to a capable elementary school teacher.

Computer Science (often called Computer and Information Science) is a new discipline. Although the first college degree programs in this discipline were started in the early 1960s, 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 now earning bachelor's degrees in computer science than in mathematics.

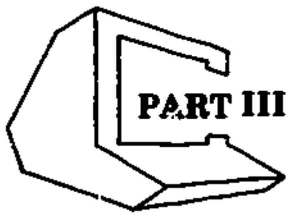
This short booklet is designed to help you *begin* to acquire a minimum level of computer literacy. A few hours of hands-on computer experience and the reading of this booklet can make a substantial contribution to your total knowledge of computers, especially as they are applied to education. But you 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 life. Newspapers, magazines, news broadcasts, television science specials, education journals, etc. all carry material about computers. Since you now have some basic knowledge about computers, it is not 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. You can probably find a computer programming course at a nearby college or university. Encourage your school system to arrange a workshop or an inservice course. If you are serious about learning more about computers, then 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 designed specifically for teachers.

There are many other aspects of computer science which have been mentioned only briefly or not at all in this booklet. Some of the sub-fields include *artificial intelligence (AI)*, business data processing, computer graphics, information retrieval, numerical analysis, programming languages, simulation, and theory of computation. The field of computer science can also be studied from an electrical engineering point of view. The design of chips and computer circuitry and the interfacing of 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 does not include this level you may need to do some extra work in math to complete the course. However, computer science and mathematics are two distinct disciplines. You do not need to be a mathematics wizard to learn about computers. Every teacher is capable of acquiring a working knowledge of computers in education.



PART III — COMPUTER-RELATED ACTIVITIES FOR THE ELEMENTARY SCHOOL

Introduction

> 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 designed specifically 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. The first two references on page 45 are excellent sources of information. Reference [3] contains about 75 additional classroom activities.

Thinking Activities: 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 (TA's) 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 TA's and read it. Then close your eyes and think about the activity. Get in touch with your body's 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 orincipal 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 at that moment your principal turns to you and says, "Can you help us on this question?" Now you are on the spot! How do you reply?

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 to try out 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. 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 asks, "Would you like to have a classroom set?" How do you respond?

TA5. You are relaxing at home one evening when the phone rings. It is a parent of one of your students. The parent offers to bring a computer to your classroom, teach you how to use it, and leave it in your classroom for two weeks. 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 few sentences or paragraphs telling something they know about computers. Have several students read their reports to the class. Young children may dictate their sentences to you instead. You may be surprised and amused at the results. Students know about computers from their parents and siblings, from television and movies, from comic books and from playing arcade games. Thus, some of what they know as fact may indeed be fiction. Discuss the results with the class.

CRA2. How do machines help people, and what problems do they create? Build a unit around this question. Students can collect or draw pictures of various types of machines. For each machine, students should indicate the problem it is designed to help solve. For each machine listed, students should think of problems 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 directly relate to computer usage or work in places where computers are an everyday tool. Have each student write a brief report on their findings. Students might also make a list of occupations, and then investigate how computers are affecting these occupations.

CRA4. One standard measure of a computer's capability 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 two MIPS. The fastest computers currently available, costing more than $10 million each, are rated at more than 100 MIPS. An instruction may involve adding or multiplying two decimal numbers, or comparing two words to see if they are in alphabetical order. 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 on this data, help each student determine how long it would take to answer a million of these questions. Explain that a computer could do this amount of calculation in less than a second.

b. A computer rated at one MIPS can examine and do some processing on one 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 that? This question involves timing students as they read a few pages, counting the number of characters on these pages, and then estimating the number of characters in the book. 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, "Try saying the words one, two, three. Then try saying one hundred sixty-five thousand eight hundred thirty-four. Which takes longer?"

CRA5. Computer scientists define the word *procedure* as follows: A procedure is a step-by-step set of instructions which can be mechanically interpreted and carried out by some agent. 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 and procedural thinking.

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 which can be 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 to look up a name and phone number in a telephone directory.

c. Select some pencil and paper arithmetic exercises appropriate to the skill level of your students. 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 25-50 cards, each containing a different number one 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 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. . . . Here the robot is given the ability to test whether a certain condition is satisfied and make a decision based upon the results. A robot with decision-making capability can, following an appropriate program, accomplish very complex tasks.

f. Students already know many procedures such as how to check out a book from a library, how to look up a number in a telephone directory, how to use a telephone, how to get from one place to another via bus or subway, how to tie a shoe, how to turn on a light, etc. 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 hand-held 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. You should be able to accumulate enough machines to try some of the following Calculator-Based Activities (CBA):

CBA1. 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. If you have a classroom set of similar calculators, you can give this instruction to the whole class. 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.

CBA2. 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.

CBA3. 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−, RM and CM keys in addition to those on a simple four-

function calculator. The extra calculator memory is useful when performing calculations such as:

(a.) 7/12 − 3/17
(b.) (89.4 × 62.8) − (16.7 × 39.5)

It is recommended that you study a book such as [1] listed in the Reference Section on page 45 before starting your students on such exercises. That book contains considerable information about the use of calculators in problem solving and the relationship between calculators and computers.

CBA4. Most calculators use decimal fractions in their calculations. Thus, 1 ÷ 3 = 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 ÷ 3; 2 ÷ 6; 3 ÷ 9; and −1 ÷ −3.

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

Computer Activities

With a computer available, you can teach using a computer or you can teach *about* the computer. The former is often known as computer assisted learning. 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 the 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. For example, if the program is written in BASIC, which is the most widely used language on microcomputers, you need only type the word RUN, and then push the RETURN or ENTER key. After that, you interact with the computer following the directions it provides. If the program has been appropriately designed, even a preschool child can experience considerable success in this endeavor.

Select a game or other "fun" activity from a program library and

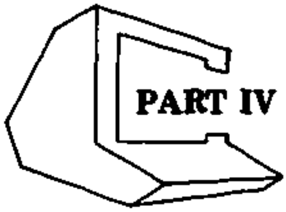
load it into your computer's primary storage. Select a student and show him/her how to run the program. Watch what the student does and answer questions as necessary.

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 you probably won't be needed. Each student in turn selects another student until everyone 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 stereo. Thus, with appropriate instruction and experience, even quite young students can master the process. Use the same aproach 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 it is a more complex procedure.

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 computer assisted learning program. Then have each student write a short report on when they would prefer to be taught by a teacher and when they would prefer a computer, and why.



PART IV — APPENDICES

References

1. Moursund, David *Calculators in the Classroom With Applications for the Elementary and Middle School Teacher*. John Wiley & Sons, Inc., 1981.

2. Billings, Karen and Moursund, David *Are You Computer Literate?* dilithium Press, 1979

3. Moursund, David. *Introduction to Computers in Education for Elementary and Middle School Teachers* International Council for Computers in Education, 1981.

Glossary

Algorithm
A step-by-step set of directions guaranteed to solve a particular type of problem in a finite number of operations

Artificial Intelligence (AI)
The branch of computer science that deals with questions such as "How smart is a computer?" and "How can one program a computer to do intelligent things?" Computers can now do many things that humans believe require substantial intelligence such as playing a good game of chess or doing a medical diagnosis.

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 used in secondary schools. Although BASIC is sometimes taught to elementary school students, there are other languages that are more suitable for use by children of this age level.

Binary digiT (Bit)
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 elementary school students.

Bug
An error, especially an error in a computer program Detecting and correcting such errors is one of the key aspects of computer programming. Elementary 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.

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)
This is 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 middle-priced modern computer system is able to process several million instructions per second

Chip
The transistor was invented in 1947 and proved to be an excellent replacement for vacuum tubes in many applications. During the 1960s people learned to manufacture a circuit containing a number of transistors and other electronic components all in one integrated unit This was called an integrated circuit. Since a small "chip" of silicon was used in the process, it was also called a chip.

Continual rapid progress in developing smaller and smaller circuitry has led to the current situation where a single chip may contain the equivalent of tens of thousands of transistors and other electronic components. Such chips can be mass produced, often at a price of well under $10 each. A single chip may form the heart of a calculator or be the central processing unit of a microcomputer.

Computer Assisted Instruction (CAI)

The use of a computer to help present instruction, to help teach students. This includes routine drill and practice, use of programmed instruction with multiple branchings depending on student answers, and sophisticated interactive systems designed to teach high level skills in problem solving. In all cases good quality educational software is necessary if the system is to be an adequate aid to instruction. Such software is very expensive and time consuming to develop.

Computer assisted learning

The use of a computer in any aspect of the teaching/learning process.

Computer Augmented Learning (CAL)

The use of problem-solving programs from a software library as an aid to student learning. Often the programs being used are similar or identical to those used to solve real world problems from business, science and industry. Students are able to tackle more realistic problems and also learn effective uses of computers as an aid to problem solving through CAL.

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.

Computer Managed Instruction (CMI)

The use of computers as a record keeper, diagnostic tester, prescriber of what to study next, and so on. The main goal is to help automate some of the management aspects of instruction.

Debug

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

Disk

A form of secondary storage designed to store large quantities of data. A disk is a flat, rotating plate coated with magnetic oxide. If the plate is made of plastic and is flexible, the disk is called a floppy disk. If it is made of metal it is called a hard disk. Floppy disks cost about $3 to $6 apiece, with the disk drive costing about $400 to $1,000. Hard disks have considerably larger storage capacity but are correspondingly more expensive, as are their disk drives.

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 are combined in 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 of books.

K

A measure of storage capacity, $K = 2^{10} = 1024$. The primary storage of a computer is often stated as a number of K bytes of storage such as 48K bytes.

Logo

A computer programming language developed by Seymour Papert specifically for children. It is an excellent language to use for introducing computers into the elementary and secondary school classroom.

Memory

All calculators and computers have storage space, where data being operated upon, operations to be performed and intermediate answers can be stored. This storage space is called memory. In no sense is it like a human mind. A good analogy is with magnetic tape, which can be recorded on, played as often as desired and then erased.

Microcomputer
A computer whose central processing unit consists of one or a few large scale integrated circuits (see *Chip*). Microcomputer systems range in price from about $200 to $8,000 or more, and hundreds of thousands of these machines have been sold in the past few years. They are becoming a common item in both homes and schools.

Microsecond
A millionth of a second. A modern, medium-priced computer can carry out an operation such as multiplying two numbers in less than a microsecond

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.

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. Language translators are one type of software that allow programmers to use languages such as BASIC, COBOL, Logo and Pascal. These programs translate from the aforenamed 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.

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 type of computer-assisted learning hardware.

Word processing
Use of a computer as an automated typewriter Paragraphs of standard materials, as well as rough drafts and complete documents, are stored in a computer memory. These may be edited or modified using a typewriter-like keyboard terminal Error-free final copy can be rapidly printed out by the computer on a terminal.

Brief Guide to Periodical Literature

The publications listed below 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 are a good example. Prices are effective as of June 1982.

1. Association for Computing Machinery, 11 W 42nd St., P O. Box 12105, Church Street Station, New York, N.Y 10249 (Membership is $40/yr., members receive the *Communications of the ACM*, published 12 times/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. ACM also 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, 409 Miller Hall, Western Washington University, Bellingham, WA 98225. (Membership is $40/yr ; members receive the *Journal of Computer-Based Instruction* published 4 times/yr. and *ADCIS News* published 6 times/yr.)

   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 16th St. NW, Washington, D.C. 20036. (Membership is $35/yr., members receive the *AEDS Journal* 4 times/yr., the *AEDS Monitor* 6 times/yr. and the *AEDS Newsletter* 10 times/yr.

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

4. *Classroom Computer News*, 341 Mt. Auburn St., Watertown, MA 02172 ($16 for 6 issues/yr.)

   This magazine features short articles plus a directory aimed at classroom teachers and school administrators at the pre-college level.

5. *Creative Computing*, P.O Box 780-M, Morristown, NJ 07960 ($24 97 for 12 issues/yr.)

   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. *Educational Computer*, P.O. Box 535, Cupertino, CA 95015. ($15 for 6 issues/yr.)

   Besides articles on computers in education, *Educational Computer* carries news on conferences.

7. *Electronic Learning*, 902 Sylvan Ave., Englewood Cliffs, NJ 07632 ($19 for 8 issues/yr.)

   Published by Scholastic, Inc., *Electronic Learning* is aimed at beginning users of calculators, computers and other electronic aids to learning.

8. *InfoWorld*, 375 Cochituate Road, Framingham, MA 01701 ($25 for 51 issues/yr.)

   This newspaper-format publication contains detailed up-to-date information about major happenings in the computer field. This is a good source of information about new hardware, software and supporting materials.

9. Minnesota Educational Computing Consortium, 2520 Broadway Dr., St Paul, MN 55113 (Free newsletter—*MECC Dataline*.)

   MECC develops educational software for Apple and Atari, as well as support booklets. Price list sent upon request

10. *Technological Horizons in Education Journal*, P.O Box 992, Acton, MA 01720 ($9.50 for 8 issues/yr as of 2/82.)

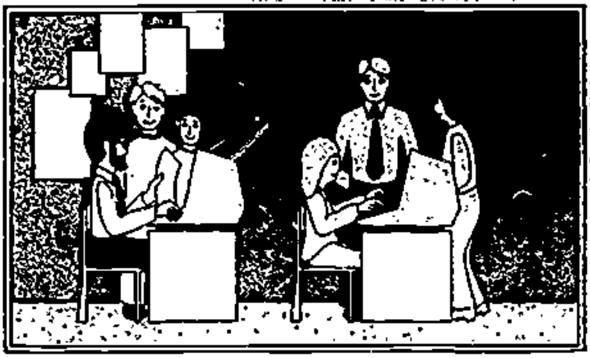
    T.H.E. Journal contains articles on educational uses of computers as well as articles on other technological aids to education. Aimed at both teachers and administrators

11. *The Computing Teacher*, University of Oregon, Eugene, OR 97403. ($16 50 for 9 issues/yr.)

    The Computing Teacher is a journal for elementary and secondary school educators as well as teachers of teachers who are making instructional use of computers or who are concerned with how computers are affecting the content and process of education Each issue contains information of use to the beginner and to the experienced computer user TCT is published by the International Council for Computers in Education, a non-profit professional organization whose goal is to further the field of instructional use of computers

INTRODUCTION TO COMPUTERS IN EDUCATION FOR ELEMENTARY AND MIDDLE SCHOOL TEACHERS

David Moursund
Dept. of Computer & Information Science
University of Oregon
Eugene, Oregon 97403



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Price $7.00 U.S.

INTRODUCTION TO COMPUTERS IN EDUCATION FOR ELEMENTARY AND MIDDLE SCHOOL TEACHERS by David Moursund, $7 on prepaid orders to ICCE. This 8½ x 11, 96-page book, published Fall, 1981, is an easy to-read introduction to computers in education. It is designed for self-instruction or for a formal inservice or preservice course for teachers. It contains an in-depth treatment of teaching about and teaching using computers at the elementary and middle school levels. The book includes over 75 activities that can be used at this educational level.

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