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ABSTRACT

This booklet is intended to acquaint educational policy-makers with some of the current roles and potential applications of computers in the curriculum, and to encourage them to initiate actions that will lead to proper and effective instructional use of computers in school systems. It is organized as a series of questions and answers designed to give an overview of computers in education, with emphasis on instructional use. For each question, a brief answer is provided in boldface, followed by a more detailed discussion. Part I answers basic questions about computers, computing, hardware, software, and programming languages. Part II covers instructional use of computers, including the kinds of problems they can solve, the categories of educational use, the role they play in problem solving, their use as learning aids, and sections addressing computer education and calculators. Part III is devoted to the problems and procedure for developing appropriate goals, followed by a discussion of anticipated costs. Part IV consists of nine appendixes, seven of which are editorials by the author reprinted from "The Computing Teacher," while the remaining two are a brief glossary and a guide to periodical literature. (TE)

SCHOOL ADMINISTRATOR'S INTRODUCTION TO INSTRUCTIONAL USE OF COMPUTERS

David Moursund

International Council for Computers in Education
135 Education
University of Oregon
Eugene, Oregon 97403

Price $3.00 U.S.

David Moursund, the author of this book, has been teaching and writing in the field of computers in education for the past sixteen years. 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's accomplishments and current involvement in the field of computers in education include:

- Author or co-author of a dozen books and booklets and numerous articles.
- Chairman of the University of Oregon's Computer Science Department 1969-1975.
- Chairman of the Association for Computing Machinery's Elementary and Secondary Schools Subcommittee, 1978-1982.
- President of the International Council for Computers in Education and Editor-in-Chief of *The Computing Teacher*.

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SCHOOL ADMINISTRATOR'S INTRODUCTION TO INSTRUCTIONAL USE OF COMPUTERS

PREFACE

Computers are now an everyday tool in business, government and industry. In most school districts computers are commonly used for tasks such as payroll, accounting, inventory and purchasing. Many school districts use computers to schedule students, test students and store student records. 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.** Data from other sources lead to estimates that by the end of 1983 there will be an average of three microcomputers per school building in the United States.

But so far computers have had very little impact upon the curriculum in most schools. Most teachers do not make use of computers as an aid to instruction. The curriculum in most schools does not reflect the current capabilities of computers or the role computers play in the lives of adults in our society. Most students graduating from our schools are computer-illiterate. This means they have little insight into the capabilities and limitations of computers, or how computers affect their lives. They do not know how to use a computer as a tool for coping with the problems they will encounter on the job or as they continue their formal education.

This booklet has two purposes:

1. To acquaint educational policy makers with some of the current roles and potential applications of computers in the curriculum.
2. To encourage educational policy makers to initiate actions that will lead to proper and effective instructional use of computers in their school systems.

This booklet is organized as a sequence of questions and answers designed to give an overview of the field of computers in education, with emphasis on instructional uses of computers. For each question a brief answer is provided, followed by a more detailed discussion. You can get a quick overview of each section by just reading the paragraph(s) in bold face, or you can gain more depth of understanding by reading the more detailed answers.

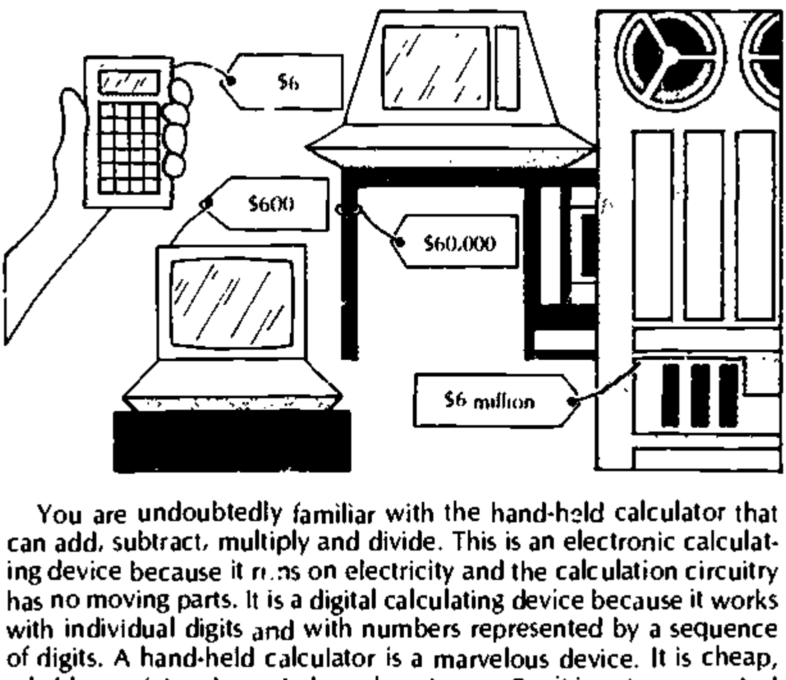
The overview ends with a set of goals and proposed actions and a discussion of the costs of achieving these goals. These are actions you can take; they are designed to improve instructional use of computers in your school system. The overall goal is to ensure that all students come to understand the capabilities and limitations of computers, and how to use a computer as an aid to problem solving.

Included in the booklet are nine appendices. The first seven are editorials from *The Computing Teacher.* The remaining two are 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.

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, in that 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.

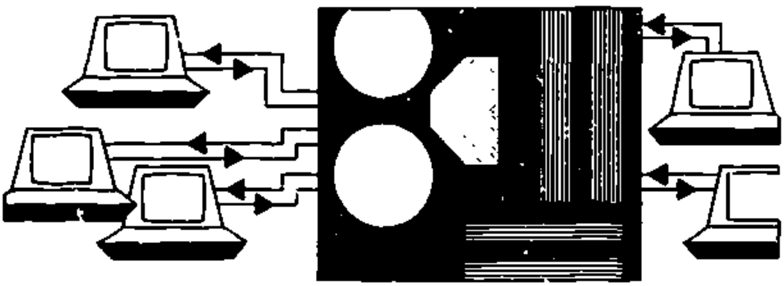
This last point is very important to keep in mind. We understand and accept that reading and writing are general-purpose skills, and that pencil and paper are general-purpose tools. **Eventually computers will gain a similar level of acceptance, and skill in their use will be expected of all educated 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 $200 to $2,000. By early 1983 more than four million microcomputers had been sold in the United States. They are now 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 1983 Radio Shack is selling a hand-held computer, programmable in BASIC, for under $100. 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.

What Is Interactive Computing?

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



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 ideas 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, became common. 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 pre-college education. Its price is sufficiently low so that every school system can afford to provide some computer facilities.

In 1980 the first hand-held computer became commercially available. Several companies introduced computers easily carried in a briefcase. In 1981 a 450,000 transistor chip became commercially available. In 1983 one brand of microwave ovens was making use of a 500,000 component integrated circuit, and million-component chips were beginning to become commercially available. Today, rapid progress in electronic technology continues unabated.

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:

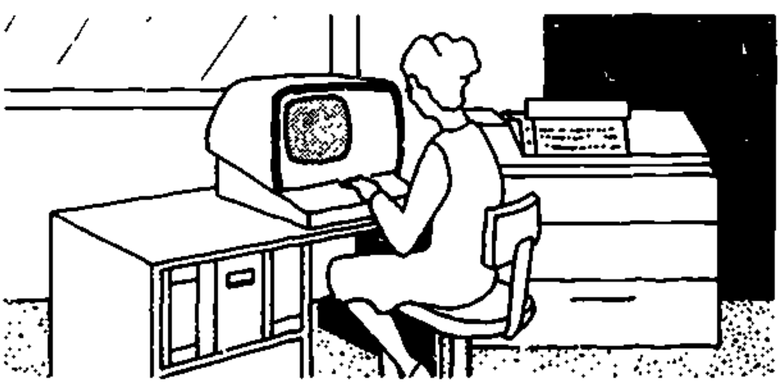
Input Unit—
Used to get information into the computer. The most common is an electric typewriter device called a keyboard terminal.

Output Unit—
Used to get information out of the computer. The most common is a television display screen, but typewriter-like and dot-matrix 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 being processed.
- *Secondary Storage—*
  A peripheral storage device that can store information in a form acceptable to the computer such as on magnetic tape, disk or drum. 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 $200, 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 Atari negotiated a special contract with the Minnesota Educational Computing Consortium. In this contract, the full cost of an Atari 400 microcomputer with one floppy disk drive 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 disk storage units, which are flat, circular plates coated with the same material used on magnetic tapes. It will have a variety of other input and output units such as an optical scanner, light pen, graphics pad, plotter and graphics terminal.

All computers are alike in that they are designed for the input, storage, manipulation and output of information. But the most expensive computers cost more than twenty thousand times as much as the least expensive computers The more expensive computers are much faster and have much larger primary and secondary storage capacities. They also have a wide variety of high quality input and output devices.

Computer hardware is general-purpose in the sense that it can be used on a wide variety of problems. But some hardware systems are specifically designed to meet business application needs while other systems are specifically designed to meet scientific research needs. An inexpensive microcomputer may be an excellent aid to instruction and to student learning but be nearly useless as an educational administrative aid. Conversely, a computer designed to fit the needs of school administrators may be quite inadequate in meeting the needs of students.

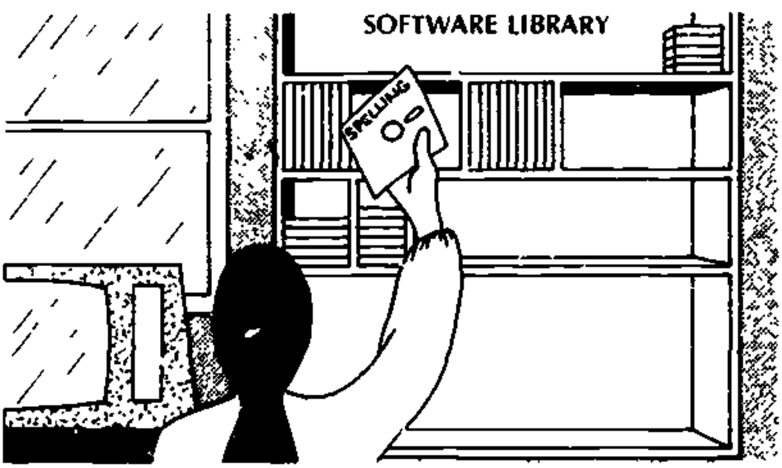
This is a very important point. An inexpensive microcomputer system can be designed to specifically meet the needs of students. Such a machine is not likely to be a useful administrative tool. Alternatively, one can design a more expensive microcomputer system specifically to meet some school administrative needs. While such a system can also be used for instructional purposes, this often is not a desirable application. The smooth functioning of a school can be highly dependent upon the functioning of its administrative computer facilities, and misuse or abuse by students could be a disaster.

The price-to-performance ratio of computers has improved by a factor of more than 100 over the past 20 years. This means that hardware capability costing $200,000 about 20 years ago can be purchased for less than $2,000 today. This rapid change has occurred during a time when inflation has steadily eroded the value of the dollar!

Similar rapid progress is likely to occur for the next 10 to 20 years. Many hand-held, battery-powered $25 toys of the year 2000 will contain more computer hardware capabilities than today's $2,000 microcomputer systems.

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 hardware is designed so that it can automatically and rapidly follow a detailed set of instructions, called a *computer program*, that has been placed in its primary storage. A computer requires software in order to perform any useful task.

Computer programs are written in computer languages such as BASIC, COBOL, machine language, FORTRAN or Pascal. Programming languages are discussed in the next section of this booklet. At one time the primary cost of using a computer was the cost of the hardware. 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 carries out mechanically 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.

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 can 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.

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.

There are many different machine languages, and programs written in one will not run on a computer having a different machine language. Since computer programs are time-consuming and expensive to develop, this is a major problem.

Computer scientists have attacked the problem by developing higher level languages such as BASIC, COBOL, Logo, FORTRAN and Pascal, that are independent of any particular machine They are designed to be relatively easy for people to learn. Computer programs can be written to translate them into machine languages. 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 language. The sample BASIC program given below can be run on dozens of different types of computers because dozens of different translating programs have been written for BASIC.

```
100 REM *           *** PROGRAM RECTANGLE ***
110 REM * DESIGNED TO ILLUSTRATE PROGRAMMING IN BASIC
120 REM * PROGRAM WRITTEN BY DAVID MOURSUND
130 REM *                  VARIABLES:
140 REM *           A = AREA OF A RECTANGLE
150 REM *           L = LENGTH OF A RECTANGLE
160 REM *           W = WIDTH OF A RECTANGLE
170 REM *           P = PERIMETER OF A RECTANGLE
180       PRINT "THIS PROGRAM WORKS WITH
            RECTANGLES."
190       PRINT "YOU SUPPLY THE LENGTH AND WIDTH,
            AND"
200       PRINT "THE COMPUTER DETERMINES AREA AND
            PERIMETER."
210       PRINT "WHAT IS THE LENGTH OF THE RECTANGLE?"
220       INPUT L
230       PRINT "WHAT IS THE WIDTH OF THE RECTANGLE?"
240       INPUT W
250 REM * USE FORMULAS TO COMPUTE THE AREA AND
            PERIMETER.
260       LET A = L*W
270       LET P = 2*L + 2*W
280       PRINT "THE AREA OF THE RECTANGLE IS";A
290       PRINT "THE PERIMETER OF THE RECTANGLE IS";P
300       END
```

Read through the program even if you haven't studied BASIC. The REM statements (REMark statements) are designed to make it easier for humans to read the program. The computer cannot read and understand REM statements. 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.

Each programming language is designed to meet the needs of a specific group of users. BASIC was designed to meet the needs of college students, although it is also the most widely-used language at the pre-college level. COBOL was designed to meet the needs of the business data processing programmers. Logo was developed for use in grade schools, while Pascal was developed primarily for computer science majors in colleges and universities. There are hundreds of other programming languages, and new ones are developed each year, although very few gain widespread and lasting acceptance.

Students at all grade levels can learn to program, provided that appropriate computer facilities, teaching and learning aids, and trained teachers are available. Some instruction in computer programming is an essential part of developing computer literacy. It takes a substantial amount of instruction in computer programming to develop a functional level of skill in writing programs to solve problems in a variety of disciplines. Thus, computer programming as a facet of computer literacy might be studied during a quarter or half-year computer literacy course in junior high school, while computer programming to develop a useful skill level might be incorporated into a year-long senior high school computer science course.

The Educational Testing Service of Princeton, New Jersey has recently announced that an "Advanced Placement" test has been developed for computer science. Students taking a high school AP course in computer science may be able to qualify for college credit. The test will be used for the first time in the spring of 1984. It will assume that students have a good working knowledge of the programming language Pascal as well as knowledge of a broad range of other computer science topics.

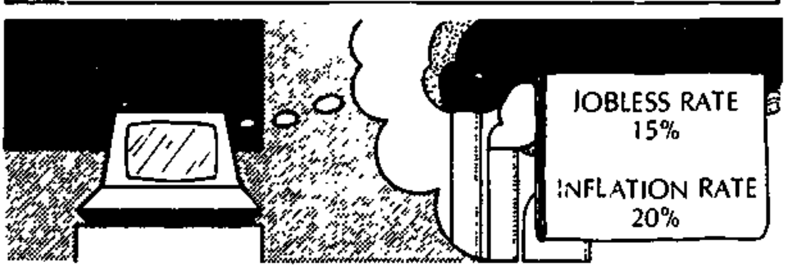
PART II—INSTRUCTIONAL USE OF COMPUTERS

What Kinds of Problems Can Computers Help Solve?

Computers are a general-purpose aid to problem solving, much in the same sense that reading, writing and arithmetic are general-purpose aids. Every student who can learn the three Rs can also learn to use a computer at a worthwhile level.

Computers are now an everyday tool throughout business, government, industry and higher education. Some typical applications include:

- Library information storage and retrieval
- Word processing in business offices
- Reservation systems for airlines, hotels and motels
- Stock market price quotation systems
- Process control and factory automation
- Solving mathematics problems in science and engineering
- As a creative and/or production aid in art and music
- Business payroll, inventory, billing
- Architectural and engineering drawing
- As part of a management information system
- As an aid to teaching, learning and research



Suppose that someone asked you, "What kinds of problems can paper and pencil help solve?" or "What kinds of problems can books help solve?" The answer in both cases is essentially every type of intellectual problem that people encounter. The same can be said for computers as an aid to problem solving.

Like paper and pencil, a computer system is an interactive medium. Like books, it can store printed materials. A third key feature of a computer system is that it can automatically and rapidly follow a detailed set of directions involving the input, storage, manipulation and output of symbols. Therefore, in many ways a computer system is a more powerful aid to problem solving than either paper and pencil or books.

Our educational system recognizes the need for every student to learn to read and write. We continually return to the "three Rs" as providing a foundation for what students need to know. Because a computer is a powerful addition to solving the same types of problems as one solves using the three Rs, we can confidently predict that eventually all students will be expected to learn to use a computer.

In the remainder of this section we will discuss a few examples of current widespread computer use. These will give some insight into the broad range of computer applications.

1. **Word processing.**
   A word processing system is merely a computerized typewriter. A typical application is in an office in which a lot of typing is done. Material is typed into a computer and stored in primary or secondary memory. Errors in printing are corrected by editing a copy displayed on a TV-like screen. The final, error-free copy is typed rapidly by the computer system.
   Word processing can also be taught to elementary and secondary students. This will have a significant effect on teachers of English and history, especially in the writing and revising of themes.

2. **Reservation and communication** systems.
   Airline, motel, car rental and stock market quotations are examples of systems which require a central data bank of information that can be accessed and updated. All such systems make extensive use of computers. Many other nationwide and international businesses are beginning to make extensive use of computerized "electronic mail" systems, which are computerized telecommunication networks.

3. **Process control and automation.**
   You may be familiar with the microprocessors being installed in microwave ovens, thermostats and automobiles. These process-control devices are versatile, reliable and relatively inexpensive. We have had extensive factory automation in this country for many years. Now computers are contributing substantially to factory automation. This even includes computerized robots that can weld parts together and screw nuts onto bolts.

4. **Engineering and science.**

   Computers are an everyday tool of many engineers and scientists. They are used for information storage and retrieval, for solving math and science problems and for engineering design work. In the latter area a computer system can be used as an interactive drawing and design system; similar systems are used by architects. Another type of application is in mathematical modeling and the computerized simulation of complicated systems. Modeling and simulation are also common tools of economists and business forecasters.

5. **Art and music.**

   Computers can be used as an aid to learning art and music, but they can also be used as an art or music medium. You may have noticed that many television programs now contain a credit line for the computer graphics technician. Computers are now a widely used tool of graphic and commercial artists. There has been a computer music journal for a number of years, and music generators are often built into microcomputers. Even quite young children can compose music to be played by a computerized system.

6. **Administrative, instructional and research aspects of education.**

   These topics are discussed in subsequent sections of this booklet.

We have repeatedly mentioned that computers are a general-purpose aid to problem solving. The main idea is that certain aspects of problem solving require reading, listening or observing. Other problems require thinking, planning and acquiring information, while still others are rather routine and mechanical such as carrying out arithmetic calculations. It is in this latter area that computers excel. More information on problem solving is on pages 21-23.

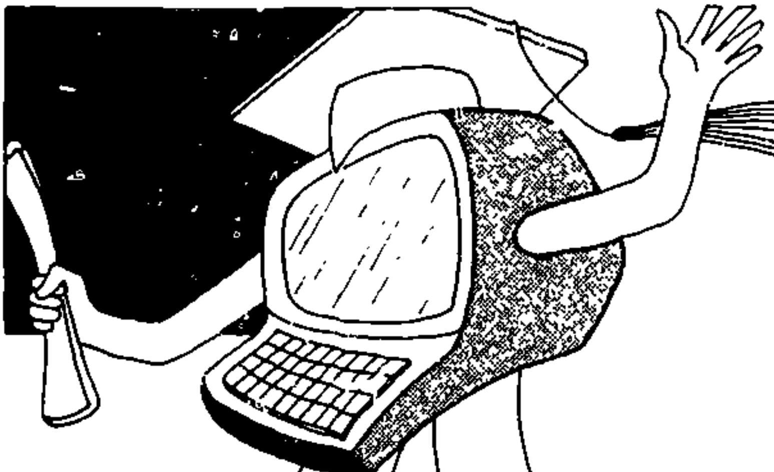
In order for a computer to solve a problem, four things must occur:

1. A program must be written.
2. Data must be made available.
3. The computer's storage capacity must be large enough to handle the program and data.
4. The CPU's speed must be adequate to solve the problem in a timely fashion.

Since these conditions are easily and economically satisfied in a wide variety of situations, there is a continuing and rapid growth of computer usage.

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 use is now beginning to grow quite rapidly.



Many aspects of running a school system are similar to running a business. There are employees who must be paid and whose records must be kept. There are supplies and services that must be ordered and inventories that must be recorded. Students must be scheduled and enrolled. Student attendance and grade records must be maintained. Changes in enrollment patterns must be detected and planned for. All of these are administrative tasks, and a computer is a useful aid in their accomplishment.

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

Computers are an essential tool to research in higher education, with about one-third of higher educational computing budgets being used for this purpose. Relatively little money is spent on comuter research in pre-college educational systems, although this type of use is growing. Two examples can be cited:

The United States government helps fund a number of educational research centers, called Educational Resources 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 which is easily made available to researchers.

For example, suppose you were interested in bilingual, bicultural 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 analysis.

The remainder of this section discusses instructional uses of computers:

- 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 students *should* be learning about computers if they are to be adequately prepared to cope with this aspect of life in our society.

What Role Do Computers Play in Problem Solving?

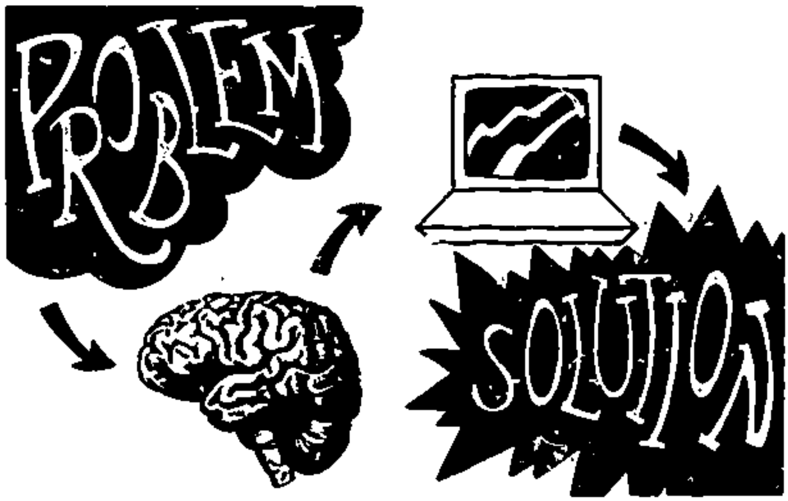
The first and foremost goal of education is to give students the tools, skills and knowledge to cope with the types of problems faced by people in our society. Both professional educators and the general public agree that reading, writing and arithmetic are essential to understanding, representing and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

A significant part of all current instruction is devoted to Step 3—carrying out the steps to solve a problem. But this is precisely the step that calculators and computers do best! We therefore need to re-examine every aspect of our current curriculum. We need to reduce the emphasis on developing a high level of "by hand," i.e., pencil and paper skill in carrying out plans, and we need to place increased emphasis upon Steps 1, 2 and 4. That is, we need to put increased emphasis on thinking and understanding.

Calculators and computers are an everyday tool of adults working in business, government and industry, however, our educational system has not yet understood the educational implications of this fact. Changes need to be made in our curriculum to reflect the increasing availability of calculators and computers to almost all adults who have need for such tools.



Of the four steps in problem solving, Step 3, carrying out the plan, is the easiest to teach and the easiest to test on standardized tests. It is evident that this step is essential if a problem is to be solved. Thus it is not surprising that our schools place great emphasis upon developing skill in carrying out routine tasks. But this is precisely what calculators and computers do best!

We can gain insight into 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 improved mental arithmetic skills, better understanding of what problem is being solved and increased experience in problem solving.

A similar type of argument can be raised concerning the use of computers in many aspects of the secondary school curriculum. Students take bookkeeping courses where they learn by-hand methods. However, computerized accounting and record keeping is now commonplace. Students take typing courses to learn to type, but they do not learn to use a word processing system when word processing, along with computerized information storage and retrieval, is becoming commonplace in the modern business office.

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 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.

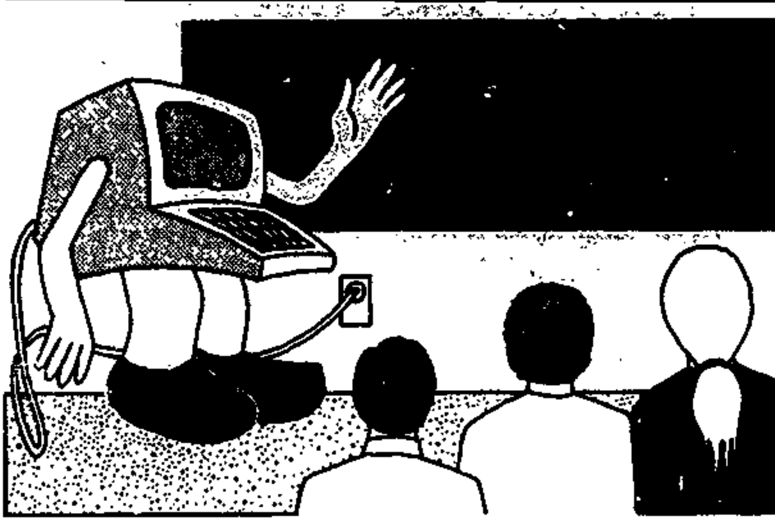
A computer's ability to draw a graph provides an excellent example. Programs now exist that allow the user to type in data an dto request a bar graph, line graph or pie chart. Within seconds a microcomputer can scale the data and draw the requested graph. Such graphs are useful in the social sciences as well as the sciences, in school administration as well as in government and business. Skill in drawing such graphs by hand is not nearly as important as knowing what can be graphed, why one would want to graph some data, how to read and use a graph, and so on. All of these higher level cognitive skills can be taught to students.

Three 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 still substantial 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. Third, all students can learn to make use of a computer as an aid to problem solving.

How Are Computers Used as an Aid to Learning?

Computer assisted learning (CAL) includes all aspects of using computers as an aid to learning. Substantial research over the past twenty-five years provides growing evidence that students can learn faster and better when assisted by a computer.

Computer assisted learning is divided into two major categories. In tutor mode CAL (ususally called computer assisted instruction or CAI), a computer fills some roles of a traditional teacher, presenting information, drilling and testing students, and maintaining records. In tutee mode CAL the student is in charge, writing programs and in other ways directing a computer to carry out his/her bidding.



The overall field of teaching and learning using computers is often called computer assisted learning. Research into this field began in the late 1950s. A few massive federally-funded projects and many hundreds of smaller projects are reported in the literature. The general conclusions are that computers can be an effective aid to teaching and learning. A major drawback has been cost. However, computer costs per student hour of usage have declined sharply since microcomputers began to be mass produced. Computers are now a cost-effective aid to instruction in a wide variety of situations.

There are two distinct points of view on teaching using computers. In one point of view the student is the recipient and the computer acts upon the student. The computer uses materials developed by a professional computers-in-education expert, and the student merely interacts with these materials.

An alternative is to have students *actively engaged* in the development of computer software that will enhance their learning. The student develops materials designed to help him/her solve problems and learn, and perhaps also designed to help other students.

Three nationally known and quite strong proponents of this approach are Arthur Luehrmann, a prolific author; Tom Dwyer from the University of Pittsburgh; and Seymour Papert of the Massachusetts Institute of Technology. Dwyer's federally-funded Solo and Soloworks projects have received wide acclaim, while the Logo language developed by Papert and others is now having a significant effect upon the computer field.

A compromise between the two points of view has gained wide acceptance. Students can learn by being acted upon by computers and by interacting with programs written by others. However, students can also learn to program and to take an active role in developing programs that will assist them in solving problems or learning.

Tutor Mode CAL is frequently called computer assisted instruction (CAI). It makes use of a computer to present instruction to students. At its simplest level much CAI material is merely rote drill and practice with the computer serving as a drill master and record keeper. There are many cheap alternatives to this such as flashcards, students drilling each other and hand-held calculator-like arithmetic drill machines. At a more sophisticated level CAI can be thought of as a programmed text. Various materials are presented to the student based on 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.

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.

Overall, CAI has proven to be educationally sound over a wide range of subject matters and grade levels. It is cost effective in areas of high educational cost such as medical school, certain aspects of military training and working with physically handicapped or learning disabled students. As computer costs continue to decline and better CAI materials are developed, we can expect CAI to play an increasing role in all of education.

The eventual role of CAI is now beginning to emerge. Well written CAI materials can accommodate differences in student learning styles, interests and abilities. They can provide an individualization of instruction that is too expensive to provide via human teachers. Over the next twenty years we will increasingly find computers being used as a primary delivery system for instruction. The role of teachers will gradually change, perhaps in ways we cannot yet foresee. This will be a definite challenge to the overall educational system—to administrators as well as teachers.

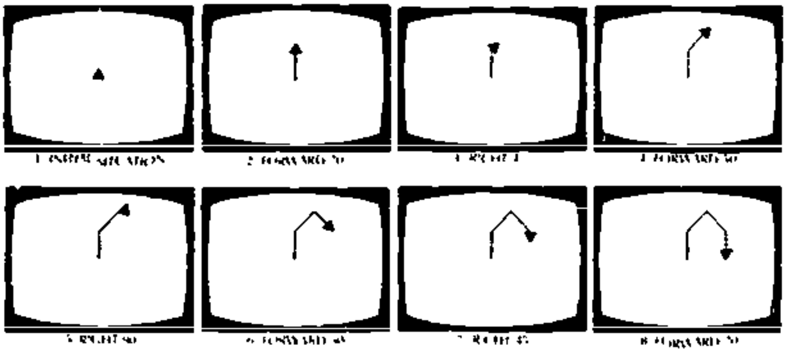
The number of microcomputers in people's homes is growing rapidly. While most are currently used for entertainment purposes, these same machines can be used in a CAI mode. There now exist quite good microcomputer-based programs of instruction in reading, arithmetic, certain foreign languages, geography, etc. It seems likely that CAI via home or public library computers will have a growing impact on schools.

In Tutee Mode CAL, a student acts upon a computer; the student is in charge, directing the interaction and learning by doing. The computer helps to provide a rich learning environment, but the computer is not preprogrammed with information to be taught to a student. Tutee mode CAL generally requires that a student learn quite a bit about a computer system and its language.

Reading provides a good analogy. A young student must expend considerable effort to master the rudiments of reading. Initially a student's aural and visual skills far exceed his/her reading skills in acquiring new information. But eventually reading skills increase and a new world opens—the printed record of the accumulated knowledge of the human race. Third graders may learn more about dinosaurs than their teachers know. A seventh grader may read about electricity, attaining a level of knowledge far beyond that of leading scientists two hundred years ago.

Similarly, students first encountering computers and a programming language in tutee mode CAL must focus upon learning the rudiments of a programming language. But eventually enough of the language is learned to open up new worlds for exploration and learning. If the computer and language system are appropriately designed, most students can move rapidly from an emphasis on the study of the computer system into an emphasis on learning other material.

The Logo language illustrates this quite well. Logo was specifically designed to be used in tutee mode CAL by elementary school students. Initial instruction may consist of learning to turn on the computer system and being shown a few simple examples. When the system is turned on, a pointed arrow called a "turtle" is displayed. This turtle draws lines as it moves about the screen following directions specified by the computer user.



Even very young children can quickly learn commands such as FORWARD, BACK, RIGHT and LEFT. FORWARD and BACK are accompanied by a distance while RIGHT and LEFT are accompanied by an angle measured in degrees. The commands have abbreviations FD, BK, RT and LT respectively.

Already the child is dealing with distances and angles; that is, with geometry. How can the turtle draw a house, a clown or a flower? After just a few minutes of instruction, the focus changes from learning Logo to the solving of some problem.

As students progress, they will find a need for additional Logo language tools. Thus, students will repeatedly switch from working on a problem to learning more about the language and then back again to the problem.

In the above example the Logo system is used to create a geometry environment. This is a rich, deep environment; an entire secondary school geometry course has been embedded in this environment.

A modern word processing system provides another example of tutee mode CAL. Such a system allows material to be typed, edited, stored and output. It also contains a spelling checker, which can help to identify misspelled words.

It requires some initial effort for a student to learn to use a word processing system. But the rewards are well worth the effort. Writing becomes more fun and correcting errors is no longer a major problem. A student can go through a number of drafts of a report or essay, trying out various ideas and continually improving the quality. The nice looking computer printout is a potent reward.

In the past, word processing has been quite expensive, so it has been used primarily in large business offices. Now, however, microcomputers have brought the cost of word processing within the reach of many millions of potential users. It is evident that most offices will eventually make use of this technology. As word processing comes into our educational system at all levels, the impact will likely prove to be dramatic. Debugging, the systematic detection and correction of errors, will become a standard part of writing. Because the final product is nice to look at, more students will collect and display their writing. Perhaps we will spawn a new generation of writers!

The key idea of tutee mode CAL is using a computer system to create a new, rich, interesting learning environment. Tutee mode CAL can provide environments such as art, music, the physical sciences, and so on. In music, for example, we know that quite young children can develop a good ear for music and can learn to play musical instruments. With an appropriate computer-based environment, the same children can also compose music. The computer interacts with the composer, stores the composition and plays it when requested. The composer (the child) creates the musical composition, edits it and experiences the pleasure of being creative.

Tutee mode CAL can be done on any computer system. But obviously it will be more successful if the hardware and software are specifically designed to facilitate learning. An interactive Logo system is far superior to a batch processed COBOL system for young children. Eventually we will have a wide variety of computer hardware/software systems specifically designed to facilitate tutee mode CAL. In some disciplines it is likely that tutee mode CAL will prove to be a more superior aid to learning than conventional modes of instruction or tutor mode CAL. In the years to come, tutee mode CAL will certainly play an important role in education.

What Should Students Learn About Computers?

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 knowledge are important in pre-college 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 and as an aid to learning. As computers have increasingly become an everyday tool for 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. Part of this is easy to obtain; for example, learning to use library programs to help solve problems is possible even at the lower elementary school level. Moreover, studies have shown that any student use of computers leads to increased computer awareness and knowledge of computers. For example, students making use of CAI over a period of time scored higher on a computer literacy test used in Minnesota.

But the other part of this goal, having students develop a useful level of programming skill, takes a substantial amount of instruction and practice. Freshman level university students find that it takes a half year to a full year course to obtain this level of programming skill.

At the pre-college level, we currently have neither the computer facilities nor the staff needed to attempt to give all students a functional level of computer knowledge. The Association for Computing Machinery (ACM) has recommended a year-long computer science course, roughly at the level of a high school biology course. Books for such a course remain to be written and teachers need to be trained. A detailed, week-by-week course outline for this computer science course, *An Introduction to Computers and Computing*, has been written by Jean B. Rogers and published by ICCE.

Novices in the computer field tend to equate computer programming with computer science. In actuality, programming is only part of computer science. A secondary school computer science course should include a substantial amount of computer programming, but it should also cover such topics as problem solving, data structures, information retrieval, modeling and simulation, artificial intelligence, computer graphics, process control and business data processing. The course should be liberal arts (rather than professional) in nature, designed to fit the needs and abilities of the typical high school sophomore or junior. It is definitely not a mathematics course, although first year high school algebra is a useful prerequisite.

A functional level of computer knowledge is a large step below a professional level. Approximately 400 colleges and universities in North America offer a bachelor's degree in computer science or its equivalent. Two year data processing courses of study are common in junior colleges and community colleges. Only a few high schools offer career-oriented programs of study in the computer field. Generally, their experience is that most of the better students in these programs go on to college rather than seeking immediate employment, even though their program of study was geared for that purpose.

We have spoken mainly about specific instruction in computer literacy, computer programming or computer science. However, computers are a useful tool in every academic discipline. Students can learn how to use computers as an aid to solving social studies problems or as an aid in effective writing. Students can learn to use computers in science as well as in mathematics. Students can learn how computers are used in music and art as well as in health and medicine. In the long ru , all teachers will need to know how computers are used in their own subject matter disciplines, so they can integrate this knowledge into the courses they teach.

A more detailed definition and discussion of computer literacy can be found in *Precollege Computer Literacy A Personal Computing Approach* by David Moursund (ICCE, 1981). Presented through an analysis of the ways students are personally involved with computers, each aspect of personal computing contributes to a set of goals for computer literacy in elementary and secondary schools.

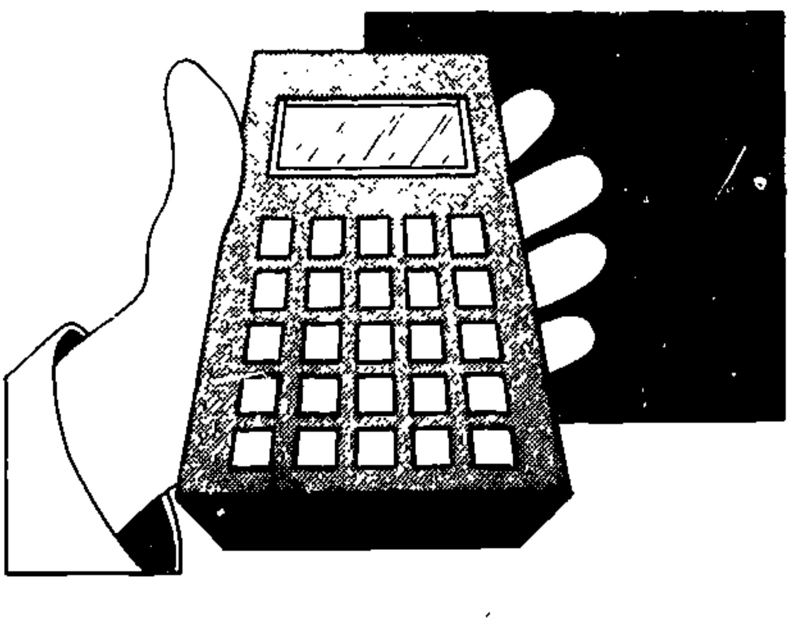
What About Calculators?

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.

At the secondary school level, calculators are useful throughout the math and science curriculum and are helpful in many business and vocational courses. They are especially useful in remedial math courses, where they allow for increased emphasis on real-world problems.

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.



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 $50.

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 paper and pencil or mental arithmetic skills. The use of calculators has been studied in hundreds of research projects, and the results tend to allay the fears. Use of a calculator does not cause a student's brain to atrophy. Judicious use of calculators does not damage the curriculum; indeed, their use can contribute substantially to it.

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

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 grade 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.

From junior high school on, the calculator can be a standard tool. Its use can be allowed in most situations, except when specifically prohibited. Thus, it may be desirable to have occasional practice in paper and pencil computation in order to maintain a reasonable level of skill. Most calculations that students need to perform can either be done mentally or with a modest level of paper and pencil skill, or are best done with the aid of a calculator (or computer).

In summary:

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

We have 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.

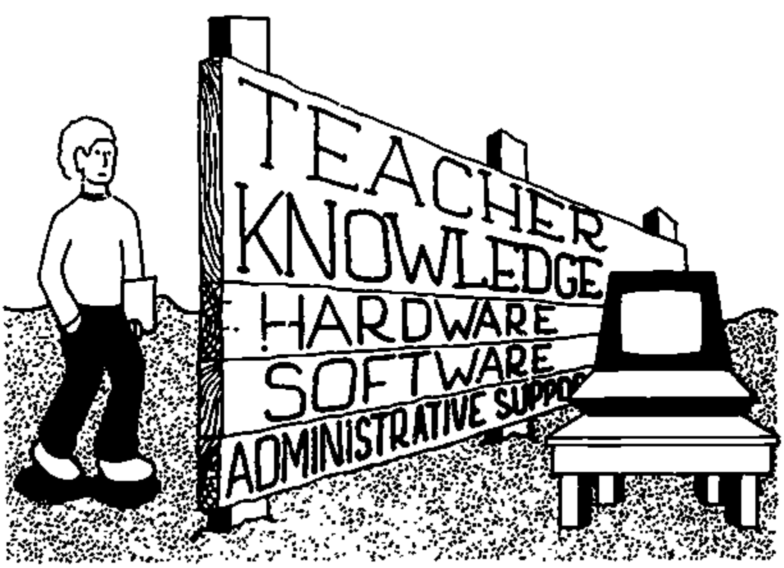
PART III—DEVELOPING APPROPRIATE GOALS: PROBLEMS AND PROCESS

What Are Some Major Barriers to Instructional Use of Calculators and Computers?

To date, calculators and computers have had only a minor impact upon the total school curriculum of most school districts. The reasons for this lack of impact are diverse, and include problems in each of the following areas:

1. Availability of hardware.
2. Availability of software.
3. Availability of courseware.
4. Teacher support.
5. Administrative and school board support.
6. Parental support.
7. Knowledgeable teachers.

Presently, the most serious problem is the lack of teacher knowledge about the use of computers in education. This problem overshadows the total of all the other problem areas.



The seven item list of barriers to the instructional use of calculators and computers is extensive, although not exhaustive. Any one of the barriers is sufficient to severely inhibit progress in extending the impact of calculators and computers on the curriculum. Although we could easily expand the list, there appears to be little value in doing so. Instead, a discussion of how the listed barriers can be overcome follows.

Computer hardware of a given level of capability has declined steadily in price over the past 25 years. Measured in terms of 1983 dollars, we can expect a continued decrease for at least the next 10 years. Calculators are now inexpensive—easily affordable by all schools. Although computers are not cheap, they are no longer expensive relative to other educational costs. Thus, the hardware problem can be overcome by only modest changes and/or additions to the school budget.

There are many companies, both large and small, in the business of developing and distributing educationally oriented software. This is a rapidly growing market which most major textbook publishing companies have now entered. It is quite difficult to develop high quality educational software, and much of the software currently available is not as good as educators would like. But in the past few years rapid progress has been made, both in the quality and quantity of software available. This trend seems likely to continue for many years to come.

Courseware refers to a combination of software, print materials and other aids for the student and teacher. Courseware is an integrated package involving the computer and traditional materials, taking advantage of the best features of each. Very little good courseware currently exists. The task of integrating computers into the overall curriculum and into the overall teaching/learning process is very difficult. But progress is occurring and will continue to be made. School administrators should pay particular attention to this integration task as computers are used increasingly in their schools.

The cost of providing an adequate level of hardware, software and courseware resources to students is well within the capabilities of almost every school district. What is needed is agreement that this should occur, and then a commitment of resources adequate to the task.

The agreement and support must come from teachers, media specialists, administrators, school boards and parents. Any one of these groups can make some progress by working alone, but overall cooperation is necessary if an adequate level of progress is to occur. In recent years, all of these groups of people have developed an increased awareness of computers. This has led to a gradual increase in support of the use of computers in education. We can expect this level of support to grow as the increased use of computers in our society becomes more extensive, and as the overall level of computer literacy increases. A school district can hasten the process by organizing appropriate workshops and open houses, designed to increase computer awareness.

By far the most important aspect of the computers-in-education problem is the individual teacher. The teacher holds the key to the success or failure of computers in education. We see this most graphically when we examine the current impact of calculators on elementary education. Most elementary teachers have little insight into the role and nature of calculators, either as an item of study in their own right or as an aid in problem solving. The same statement holds true for computers at all levels. Few teachers have had the opportunity to experience the use of computers or to receive formal training in their use.

A school district planning to make substantial use of calculators and computers in instruction must implement a major inservice training program for teachers. This program must be integrated with acquisition of appropriate hardware, software and courseware. It must be a long-term, comprehensive plan, designed to reach the majority of all teachers at all instructional levels.

It is appropriate and desirable to include higher education representatives in the development and implementation of an inservice training plan. Moreover, higher education needs to implement a corresponding level of computer education into its own teacher education program. It is no longer acceptable for higher education to produce newly-graduated teachers who are computer-illiterate.

If a school district makes a major commitment to instructional use of computers, it will need to provide high level administrative support and guidance to this area. Most likely it will need to create a position of Computer Instructional Specialist and fill the position with a person who has a high level of training and experience. Curriculum specialists in other academic areas generally have at least a master's degree in their field of expertise. So it should be with the computer field. The computer instruction expert needs to have broad knowledge in computer science and in all levels of the curriculum.

What Are Appropriate Goals for the Instructional Use of Calculators and Computers?

A number of statewide and/or national groups have recommended goals for instructional use of calculators and computers. There is considerable agreement on the following main goals:

1. All students should become computer literate. This means that they should gain a substantial level of computer awareness and develop a functional level of skill in using computers as an aid to problem solving in a variety of disciplines.
2. Teaching using computers (tutor and tutee mode CAL) should gradually grow in importance and use. Teaching using computers should occur only when it is an educationally and economically sound aid to the instructional program.
3. All aspects of the current curriculum should be reconsidered in light of the existence and widespread availability of calculators and computers. Modifications should be made to take into consideration the capabilities and applications of these machines.
4. Secondary schools should begin to provide solid programs of computer-oriented instruction, both for students who will seek jobs upon leaving high school and for those who will go on to college.

The overall goal is to integrate calculators and computers into the curriculum at all grade levels and in all subject matter areas, both as an area of study and as an aid to instruction. To do this requires the following:

1. Agreement that it should be done.
2. A plan.
3. Resources and time to carry out the plan.

The Conference Board of the Mathematical Sciences is a national organization of math-oriented professional societies in the United States. In 1972 it proposed and recommended that computer literacy be integrated into the junior high school curriculum. In more recent years, similar recommendations with a goal of universal computer literacy have been voiced by the National Council of Teachers of Mathematics (NCTM) and the Association for Computing Machinery (ACM).

Many individual schools and school districts have recently decided that it is time to expend significant effort in dealing with the problems of comput s and calculators in education. This appears to be a nationwide tre , suggesting that there is rapidly growing support from teachers, administrators, school board members and parents.

Let us assume, then, that agreem has been reached that something needs to be done. The next ste planning, beginning with a study of what is currently being done with calculators and computers in the school district. This study and the overall planning should involve representatives from all concerned groups, including teachers, media specialists, administrators, school boards, parents and the community. Outside help from college and university faculty or professional consultants may also prove helpful.

Planning involves the setting of goals and a timeline for the accomplishment of the goals. It involves an examination of currently available resources and consideration of how the necessary additional resources will be made available. The plan must address hardware, software and courseware acquisition. It must pay particular attention to the issue of teacher training.

Although the details of such a plan will vary from one school district to another, some generalizations can be made. Certain aspects of implementation of the plan can begin before a detailed total plan has been completed. Thus, if it is clear that there will be increased use of calculators and computers, it is appropria e to implement the following steps:

1. If your school or district has not already done so, acquire a substantial number of calculators. Begin offering workshops to teachers on appropriate uses of calculators. Integrate calculators into the curriculum.

2. Begin to acquire a reasonable amount of computer hardware, enough to facilitate inservice teacher training programs. Begin to offer inservice courses for teachers, media specialists and other support staff. An important part of an inservice course is hands-on experience in the use of computers in the classroom. Every teacher in an inservice course should have a computer to use in his/her classroom. The teacher should be allowed to use this computer at home on evenings and weekends.
3. Begin to acquire and/or develop software and courseware. Provide for the storage and use of these materials.
4. Begin to plan for the time when your school will have a large number of computers such as one computer per ten students. Where will they be housed? How will they be used? How will they be supervised?

A district's overall plan for the instructional use of calculators and computers may take many years to develop and implement. Provisions must be made for periodic reexamination and revision of the goals. Continued rapid changes in the cost of hardware and in the availability of appropriate software and courseware should be expected.

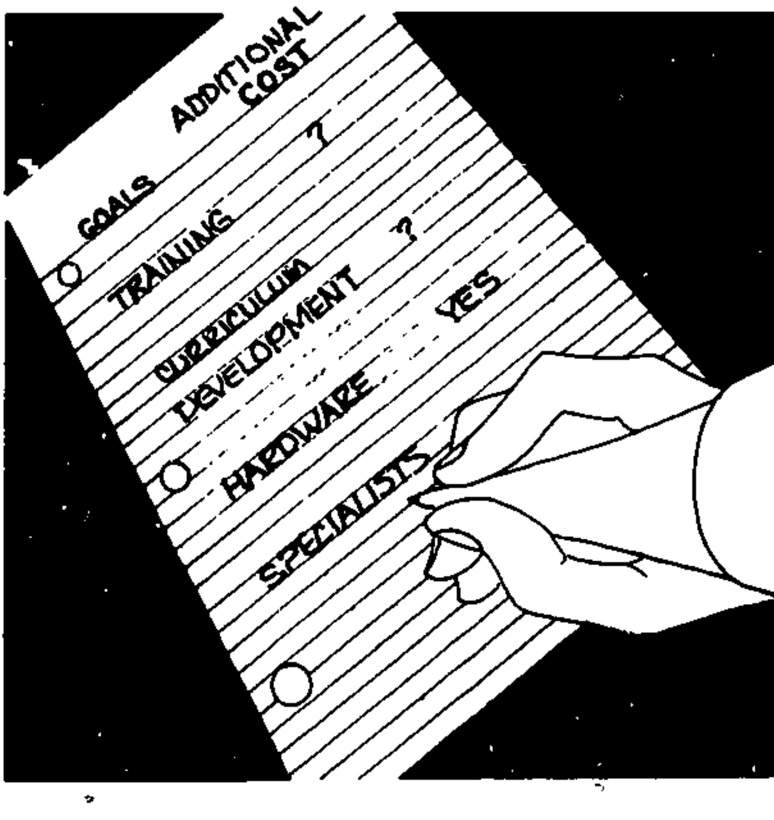
It should be recognized that the current trend is for increased emphasis on microcomputers. These machines will continue to grow in capability. Already the $2,000 microcomputer system of today is roughly comparable to the $200,000 computer system of 20 years ago. But microcomputers are not the entire answer to instructional computing. Timeshared computing provides communication between users, access to centrally located, very large secondary storage, and access to high speed printing devices.

It appears likely, then, that a combination of microcomputers and timeshared computing will ultimately be needed to appropriately serve instructional computing. The microcomputers will be used in both a stand-alone system and as terminals to the timeshared system. Long term planning should keep this idea in mind, and move towards this goal if it seems appropriate to the school system's needs.

What Will It Cost to Achieve the Goals?

The costs for implementing the goals for instructional use of calculators and computers will depend on how rapidly they are implemented, the depth to which they are to be achieved and current availability of relevant resources.

1. Teacher training is essential. But most school districts already spend a significant amount of money in this area.
2. Software and courseware need to be acquired or developed. But most school districts already spend money for curriculum development and for books and other support materials.
3. Calculator and computer hardware must be made available at an increased level. This is apt to require increased expenditures.



There will be two distinct types of costs: "out of pocket" expenses and the cost of existing resources which will be redirected. Out of pocket costs can be kept to a minimum. The cost of existing resources which can be redirected can bear most of the initial costs in working towards the computer education goals; however, over the long run, computers are apt to increase the cost of education. (This will be discussed in more detail later.)

A school district has substantial discretionary resources in terms of time and energies of its personnel, materials and supplies money, and so on. For example, a curriculum specialist can work on computer aspects of the curriculum or on other topics. An inservice day or professional meeting can focus on computers or on other topics. Libraries and resource centers can choose to buy computer or calculator books, journals and other computer-related materials. Many school systems have a computer facility and staff oriented toward administrative computing. Some of this staff and/or part of the facility might be devoted to instructional applications.

Currently computers are an "add on" expense. They are not being used to replace existing personnel, nor do they lessen the need for supplies or other equipment currently being used. Indeed, computers require maintenance and repair. They use supplies such as paper, magnetic tapes and magnetic disks.

Over the long run, however, computers have the capability of taking over some functions currently performed by teachers, their aides and/or specialists. A computer can patiently drill a student who has reading or arithmetic problems. A computer can provide advanced instruction for gifted students. A computer can score multiple-choice tests and maintain grade records. A computer can aid in the preparation of individualized programs of study for learning-disabled students. Such computer use can allow existing personnel more time to work with individual students.

It is interesting to contemplate the effect of increasing a current school budget by 1% and dedicating this increased funding exclusively to the acquisition of calculator and computer hardware. The typical school system now spends in excess of $3,000 per student per year. Thus we are talking about an extra $30 per student per year for hardware.

Good quality "solar-powered" calculators now retail for under $10. A school district bulk purchase would get such calculators for under $7 each. These machines require no maintenance and the solar batteries function well under classroom lighting conditions. A four-year life expectancy for such machines is not at all unreasonable. Thus, a yearly expenditure of less than $2 per student per year is needed to eventually provide every student with full access to a calculator.

Good quality microcomputers, with quantity discounts, are readily available in the $800 to $1,600 price range. A typical microcomputer system, well suited for school use, might cost $1,200, and have a useful life expectancy of 4 years. Large organizations such as Minnesota Educational Computer Consortium (MECC) have been able to negotiate even better prices. (If one is willing to get by with just a tape cassette player for secondary storage and with no "hard copy" printed output, good quality systems are available for about half of this figure.) Yearly expenditures of $28 per student per year would eventually result in a school system having about one microcomputer per 15 students. This is enough to give each student about an hour of hands-on experience per week. This level of computer access is higher than the average access currently provided at colleges and universities in the United States!

The point we are making is that a school system can make substantial progress in solving the computers-in-education problem using just its existing resources. A modest addition to its budget would make available a considerable amount of appropriate hardware. This level of hardware would be adequate to support a district-wide, indepth plan to address the calculator and computer literacy problem.

A note of caution: Early in this booklet it was mentioned that computer software can frequently cost more than hardware. If a school system decides to develop its own software, it is apt to find how true this assertion is. Some school districts, and the whole state of Minnesota via MECC, have been very successful in developing educational software. But most school building and school district level software development efforts have not yet produced software that is competitive with products that are now readily commercially available.

Another potentially great expense is personnel. If a school district has only six microcomputers, then no added personnel is required. But suppose a school district has hundreds of microcomputers, used in every classroom in every school building. Now the overall task of computer acquisition, maintenance, repair and supplies is greatly increased. Acquisition and dissemination of software and courseware are major tasks. Teacher training and curriculum revision are a continuing problem. One or more full time instructional computing specialists, with a broad knowledge of school curriculum and computers, are necessary. Such a staff adds substantially to the cost of computers in instruction.

PART IV—APPENDICES

The following editorials were written by David Moursund and appeared in *The Computing Teacher*.

Beware of Saber-Toothed Tigers

[Reprinted from TCT Vol. 8 # 5]

I came across an old but quite modern book this past week. *The Saber-Tooth Curriculum* by J. Abner Peddiwell is published by McGraw-Hill and carries a 1939 copyright. The book is short, easy to read, amusing and frightening in its insights. In this book a caveman gets the idea that children can be taught useful skills. Soon a formal curriculum is developed, designed to fit the needs of the times. Children are taught "fish-grabbing" (the bare-handed catching of fish); "horse-clubbing" (clubbing the type of small horse used for meat); and "tiger-scaring" (using fire to scare away the saber-toothed tiger). The book then traces the evolvement of this curriculum, with the eventual development of higher education, teacher training and educational research. The curriculum and educational system gets more and more sophisticated at teaching fish-grabbing, horse-clubbing and tiger-scaring—although the need for these skills eventually completely disappears. The story ends just before one learns what becomes of a society whose educational system is unable to change in a changing world. But the message is clear, and seems even more relevant now than in 1939.

A computer system is a new way to store accumulated knowledge. A computer can store knowledge in a passive form, much like a book. But there is much knowledge that a computer can store in an active form—the machine both stores the knowledge and is able to carry out procedures to solve problems using the knowledge.

A simple example is provided by a calculator. It "knows" how to add, subtract, multiply and divide. In the December 1980 issue of *The Arithmetic Teacher*, Grayson Wheatley, a well known mathematics educator, discusses his findings that approximately two years of the typical math curriculum in grades 1-9 is spent teaching paper and pencil long division of multi-digit numbers. He suggests that students instead be allowed to use a calculator and that this time could better be spent on more relevant topics.

We can easily laugh at the idea of teaching fish-grabbing, horse-clubbing and tiger-scaring. But most of us have trouble seeing similar topics in our current curriculum. "What! Not teach long division of multi-digit numbers? But what if one's battery goes dead?"

Computer science is making tremendous progress in developing knowledge-based systems. These are computer systems that contain a large amount of knowledge about a particular type of problem or problem area, and how to solve problems in that area. A calculator "knows" how to solve a long division problem—it merely needs to be told what problem to solve. Similarly, many knowledge-based computer systems know how to solve a wide range of math, science, engineering, medical and business problems. Hundreds of researchers are working to extend the capabilities of these systems. By and large these researchers build upon work that has already been done, so progress is cumulative and the knowledge-based systems become more and more capable.

This progress in computerized knowledge-based systems has had almost no impact upon our curriculum, even at the university level. We see a little progress in some college statistics courses, and we see perhaps more progress in some engineering-oriented programs of study. By and large, however, our curriculum seems very slow to change. It has a tremendous investment in teaching "by hand, traditional" methods.

As a teacher, I am disturbed and somewhat frightened by the fact that skills that took me years to learn and more years to learn to teach are not very important anymore. It is certainly easier to continue to teach what has been taught in the past, from time to time making small changes in teaching methods in an attempt to teach it better. But I am fighting against this tendency in myself, and I am continually working to understand what it is people should be learning in the light of the increasing capabilities of knowledge-based computer systems. It seems clear to me that students need to learn to use these systems, to work with computers rather than in competition with them. We need to examine the entire curriculum in the light of computer capabilities. This must be a continuing process, since computer capabilities are rapidly increasing. We must work to make our curriculum relevant to the needs of our current and future world. The saber-toothed tiger is extinct.

On Being a Change Agent

[Reprinted from TCT Vol 9 #6, February 1982]

If our technologically-oriented society continues, then eventually computers will be commonplace. Children will grow up in homes, schools and neighborhoods in which everyone uses computers.

Computerized information retrieval, word processing and problem solving will be as widely used as paper and pencil techniques are today.

But that "eventually" may be a long way off. Sure, hardware can be mass produced, and hardware progress continues unabated. Sure, a piece of high quality software can be widely distributed, making the cost to each end-user quite reasonable.

Unfortunately, knowledgeable end-users cannot be mass produced. The computer is a powerful tool, but it is a complex tool. To use a general range of computer capabilities effectively takes considerable ..nowledge, training, experience and a measure of courage.

That is where you and other educators come in. You are a computer-knowledgeable educator, capable of helping others to learn about computers. Thus, you are a change agent.

Being a change agent can be fun. It is being a leader, rather than a follower. It is exploring new worlds, facing new problems. It is taking risks. The personal growth rewards can be high.

But being a change agent is stressful. This is especially true in the computer field. "How do I know what I am doing is right?" "The computer field is changing so fast—how can I possibly keep up?" "Others seem to know so much more than I." "The field hasn't been researched very well. I fear that I will do more harm than good." "I don't have time to keep up in the field where I got my degree. What chance do I have in the computer field?"

Do you have any of these doubts? I have had all of them, and they continue to reoccur periodically. Be aware that these are common fears. Here are some ways to deal with them.

RELAX! PAUSE FOR A MOMENT. TAKE A COUPLE OF DEEP BREATHS. REALIZE THAT YOU ARE "DOING A NUMBER" ON YOURSELF.

If you are a regular reader of *The Computing Teacher*, then undoubtedly you are in the upper five percent of all educators in terms of your computer knowledge. You know a lot, both relative to other educators and relative to most students. You know enough to help others learn, and you know enough to do some things that will reduce the stress on you.

1. Admit freely and openly:
   a. That you don't know as much as you would like to know about computers, but you are still learning.
   b. That you feel it is very important to help others learn about computers, and that you are committed to doing so.

   This type of open and honest attitude is beneficial to you and to your colleagues. It is intellectual honesty—an excellent role model for student.

2. Learn from your everyday environment. You are surrounded by easily accessible opportunities to learn. For example:

   a. Talk to your fellow educators about current and future applications of computers. As you try to express your insights you will receive valuable feedback as well as hearing the insights of others.

   b. If you are a teacher, think carefully about what you teach. Then discuss the problems of computers in education with your students. Learn from them as you help them to begin to understand the role of computers in your teaching area.

   c. Watch science-oriented television programs, especially those on PBS. You will see that computers are an everyday tool in modern science, and you will learn some of these computer applications.

   d. Pay attention to computer and other electronics-oriented ads. Browse in an electronics store. Visit an electronic arcade center.

3. Take a course. (Or, if you can't do that, buy a computer-oriented book and read it.) Check your nearby college or university. Perhaps you can get your school district to arrange an appropiate course. If you can't find what you need, encourage your school district or a nearby school to create an appropriate course.

4. Finally, continue to be a change agent. Eventually you, and thousands like you, will be successful. Then you will be surrounded by computer-knowledgeable people, and you will no longer need to be a change agent in this area.

The Free Enterprise System

(Reprinted from TCT Vol. 10 #2, October 1982)

I was tempted to title this editorial message ENTREPRENEURSHIP but I feared such a title might attract even fewer readers than usual. An entrepreneur is "one who undertakes to start and conduct an enterprise, assuming full control and risk." I want to discuss some roles of entrepreneurs in the field of computers-in-education.

Our traditional idea of an entrepreneur is one who develops a new product and starts a company to sell it. Certainly, the microcomputer field provides an almost endless list of successes and failures of this sort, both in hardware and in software. The Apple Corporation provides a splendid example of a success story.

But I want to talk about a different sort of entrepreneur, the individual teacher or school administrator. To get started, it seems to me that it was about three years ago when the French national government announced a ten-year plan to place 10,000 microcomputers into French schools. That would be equivalent to the United States government announcing plans to place about 40,000 computers into U.S. schools, since France has about a fourth the population of the U.S.

France has an educational system that is highly centralized and one with considerable uniformity throughout the country. The national government controls the educational system. The ten-year proposal to acquire 10,000 microcomputers also included plans for teacher training.

I wondered at the time whether the United States would be able to match this rate of computers-in-education progress. It seemed unlikely that our government would be willing to purchase and give away 40,000 microcomputers. And federally funded teacher education of this magnitude seemed out of the question.

Three years have now passed. There are approximately 100,000 microcomputers in United States schools. This figure seems likely to increase to 200,000 in the next year or two and is likely to continue its rapid growth for years to come.

Teacher education has also been rapid, but it is more difficult to quantify. For example, I estimate that the number of universities offering a master's degree in computer science education has tripled in the last three years. In-district inservice workshops and short courses have likely increased a similar amount.

How can such rapid progress be occurring without effective national education policy or leadership? One might guess that it is because of educational leadership at the state level. But that is not correct. Minnesota, with its Minnesota Educational Computing Consortium, is a rare exception. Few state legislatures have provided significant amounts of money earmarked for educational use of computers.

The answer is the individual educator. Individual teachers and individual school administrators have undertaken to "start and conduct" computers-in-education enterprises, "assuming full risk and control." Their risk is usually not measured in dollars, but rather it is the risk of exploring new territory and venturing into the unknown. Their rewards are not measured in dollars, but rather in growth in self-esteem, growth in knowledge, and the awareness of making a significant contribution to education.

The growth of educational computing in the United States has not been even. I suspect that to a large extent this is due to variations in the degree of educational entrepreneurship that is allowed in different parts of the country. Even in neighboring towns one can find a repressive, "controlled" educational system and a progressive, entrepreneurial educational system.

The educator-as-entrepreneur idea need not be limited to computers in education. In every professional aspect of an educator's life there is opportunity for starting and conducting new enterprises, for risk-taking and control-taking. Some school systems and school administrators are very good at harnessing this huge source of energy. They help to create an exciting, progressive atmosphere for teachers and students.

Others have lost their entrepreneurial spirit, or never had much to begin with. They cannot readily respond to change or make effective use of the untapped potential of their building level administrators and teachers.

Computers provide an interesting and challenging test for a school system. Some are succeeding quite well, while others are failing. It is here that the analogy with business breaks down. When a business entrepreneur fails, the business goes bankrupt and the entrepreneur loses money. But when a school system fails to provide progressive, high quality education it is the students who suffer. Ultimately, the whole country and the world suffer, as the untapped potential of these developing minds becomes a lost resource.

The Unchanging Conventional Curriculum

[Reprinted and edited slightly from TCT Vol 10 #4, December 1982]

I divide computers in instruction into three major parts. Learning using computers (often called Computer-Assisted Learning) and learning about computers receive the most attention. There the goals seem clear. We want CAL to be used if students will learn more, better, faster, at little increase (or decreased) cost. We want all students to become computer literate (that is, to obtain a useful-tool level of knowledge about computers and their effects).

A third major aspect of computers in instruction receives little attention and seems not to be understood by most educators. It is the potential impact of computers upon the content of the conventional curriculum.

When I try to explain this third area, I invariably use calculators as an example. In 1965 the first desk-top electronic digital calculator was produced. It was the same size and same price (about $1,500) as the electromechanical calculators of those days. It performed the same four functions with the same accuracy, but was faster and quieter.

Up to that time there was no reason that calculators should have a significant impact on the curriculum in grades 1-8. If a person was going to use mathematics to solve problems, then the person needed to add, subtract, multiply and divide. The fact that $1,500 machines could do the same thing was of little consequence. That amount of money would buy a new car—certainly such an expensive tool as a calculator could not be made available to young students. Indeed, four-function calculators were too expensive to be readily available in business, government and higher education at that time.

We all know what has happened to the price of calculators. Now one can purchase a solar cell-powered, handheld, four-function calculator with four key memory for as little as $10. Such a calculator doesn't even have an on-off switch, since its batteries provide sufficient energy under any light conditions that allow one to read a calculator display.

At one time I expected that inexpensive calculators would drastically change the elementary and middle school mathematics curriculum. After all, a major goal in math is problem solving. Calculation is a necessary evil in problem solving, but rarely an appropriate end goal in its own right. If all students were provided with calculators, perhaps half of the time spent in math instruction in grades 1-8 could be devoted to higher level thinking, problem solving, geometry, statistics and logic. The golden age of mathematics education would be upon us.

That has not happened, despite the encouragement of the National Council of Teachers of Mathematics and many of the country's leading mathematics educators. Certainly the reason for this has not been the cost of calculators. Nor has it been that teachers cannot learn to use calculators. Almost all teachers have calculators for their own personal use. It isn't an absence of materials. Many books have been written for teachers and for students. (I am the author of one and co-author of another. Neither has sold well.) *The Arithmetic Teacher* has carried numerous examples of calculator activities for the elementary school student.

Now we have computers, and they also are getting increasingly inexpensive. Eventually they will be commonplace in homes, as they are rapidly becoming in all work environments where they are used. The parallel with calculators is frightening. Right now we have the arguments that computers are still too expensive, too fragile, too easy to steal, not available. Added to this we have the argument that computers are difficult to use, difficult to learn to use, and that most teachers don't know how to use them. These are almost the same arguments advanced against calculators a few years ago.

But all of these "barriers" will be overcome. It is now clear that CAL will gradually play an increasing role in instruction, and that eventually it will play a major role. It is now clear that computer literacy will become a standard educational goal, and that all students will learn about computers.

We *will* get better and better computer-assisted learning systems, designed to help students master paper and pencil arithmetic. We *will* get better and better CAL systems to help students learn historical science laboratory techniques. We *will* get better and better CAL materials that help students learn paper and pencil graphing techniques and equation-solving techniques.

But will the conventional curriculum content be changed? If so, how?

I believe that the way to approach this third area of computer application is through teacher education and experimental projects. The projects might be funded at the school, district, state or national level. Certainly, this is a good place to put some federal funds. But even an individual school can try out and implement such changes if they have sufficiently knowledgeable teachers.

We are beginning to see what "sufficiently knowledgeable" might mean. The typical elementary school teacher who has a calculator for personal use is not sufficiently knowledgeable about calculators unless that teacher understands mathematical problem solving and higher level goals in math education. Similarly, the typical computer-using secondary school teacher may not be sufficiently knowledgeable about computers. It is not enough to merely be a computer *user*, one who can master the use of programs. Rather, we need teachers with deep insight into their disciplines and the roles their disciplines play in business, government, industry and research. Teachers need a deep level of knowledge of the computer tool and specific knowledge of the role computers could be playing in the curriculum.

I Don't Know

(Reprinted from TCT Vol. 10 # 5, April 1983)

A few weeks ago I was walking down the display aisle at a large computers-in-education conference. Within a period of a few minutes I was "accosted" by three different individuals.

Individual #1: "What do you think of—(a particular piece of courseware)? Don't you think it's really neat?"
My response: "I'm sorry, I haven't tried it yet."

Individual #2: "What do you think of—(a particular new piece of hardware)? Do you feel it will really take hold?"
My response: "I'm sorry, I haven't seen it yet."

Individual #3. "My school wants to use computers for—(briefly describes a particular problem). What do you recommend?"
My response: "I'm sorry, I don't know very much about specific hardware and software in that particular area."

Do you see the pattern? It is one in which I am continually apologizing for my lack of expertise. I am continually made to feel inadequate.

It isn't as though I don't know quite a bit about the field of computers in education. I taught my first course to high school students in this field in 1963, and I began to teach teachers in this field in the summer of 1965. Since then I have worked very hard to learn more about computers, computers in education and teacher education. I am a good student and I have made substantial progress.

Part of the problem is psychological, and it is here that my past comes back to haunt me. My bachelor's, master's and doctor's degrees are all in mathematics, as were my initial teaching experiences. I was taught (that is, strongly indoctrinated) that a bachelor's degree in mathematics qualifies a person to teach precollege mathematics. If one is an especially strong student, the bachelor's degree earns one a graduate teaching assistantship and minimally qualifies one to teach freshman college algebra courses.

With a master's degree and more teaching experience, the graduate teaching assistant is allowed to teach an introductory calculus course. The "really advanced" graduate student in mathematics might even be allowed to teach sophomore level courses!

The general model that I learned for math teaching was that one should be totally competent. A good math teacher must be able to explain every topic and solve every problem arising in a course. Indeed, the goal was to be able to do this in real time, off the top of one's head. It was not appropriate to respond to a question with, "I don't know."

I don't know—let's learn together! It seems like a simple idea, and it is a healthy attitude for all educators. Roughly speaking, I find that elementary teachers most easily implement the "I don't know—let's learn together" idea, followed by junior high school teachers, high school teachers and college teachers, with university teachers at the bottom of the list. I can see why I have trouble—especially when my math background is factored in!

"New" math notwithstanding, the content of the K-16 math curriculum is quite old. It is difficult to find a major topic in this curriculum that is less than 50 years old, and most of the content is hundreds of years old.

Computers in education is just the opposite. Almost everything is less than 50 years old and much of it is less than a couple of years old. Hundreds of companies are developing new hardware and software. Literally thousands of people are trying out new ideas, developing new curricula and carrying on research. Computers are both a relevant aid to problem solving and a source of problems in every academic discipline at every academic level. This relevance is growing rapidly.

So, what is a middle-aged, retreaded mathematician to do? Certainly I can continue to learn. That is essential.

But it is equally essential to overcome the psychological barrier. I need to learn to say, "I don't know —let's learn together" **without following it by an apology.** There is nothing wrong with not knowing about the latest piece of hardware or software. There is nothing wrong with not carrying around in one's head all of the fine details of a particular machine that some bright 14-year-olds seem to memorize so easily. I am still a competent person even if a 14-year-old knows many things about computers that I don't know.

For me, what is especially important is learning to take advantage of my strengths, such as wisdom and experience gained through the past 46 years. I have a greater breadth and depth of knowledge than most of my students. I have had a greater range of experiences, and I have had more practice in learning to learn. If I keep these facts firmly in mind, I can more easily say, "I don't know—let's learn together." For me, that is an important goal.

District Inservice Planning

(Reprinted and edited slightly from TCT Vol. 10 #7, March 1983)

Most major school districts have begun to offer inservice workshops and courses in computers in education. I am surprised and disappointed at the lack of careful, long range planning that characterizes most of these inservice programs.

I feel that the logical starting point for planning is with a district's overall goals for computers in instruction such as the revised Cupertino goals in this issue. If a district doesn't have a set of goals, I recommend the "standard" ones mentioned in previous editorial messages.

1. A funcational, working-tool level of computer literacy for all students.
2. Computer assisted learning to be used when it is educationally and economically sound.
3. The entire K-12 curriculum to adequately reflect computers as an aid to problem solving and as a source of problems.
4. Special computer and information science courses to be made available for vocationally-oriented students and for college-oriented students.

As a school district works to define and adopt such goals, it should keep in mind that the first grader of today will spend his/her adult life in a society in which almost all people will have easy, everyday access to computers. (The analogy with current calculator access is useful.) Ten years from now computers will be readily available in schools, homes and places of work.

After deciding upon student and curriculum-oriented goals, a district should plan on how to meet the goals. The Albany School District Computer Education plan in the January, 1983 TCT is an example of a planning document. The necessary resources might be divided into three categories:

1. Computer hardware, software and courseware.
2. Resource materials such as books, course outlines, films, video tapes, and so on.
3. Computer-knowledgeable teachers and administrators.

It is evident that there are tradeoffs among these needed resources. But there is no adequate substitute for teacher and administrator knowledge. A good plan to increase this knowledge might take into consideration four general groups:

1. All teachers.
2. Teachers who are, or who will become, building level and district level resource people or specialists.
3. School administrators.
4. Lay people, especially school board members and parents.

The typical approach to reaching all teachers is via a half day or full day workshop during a scheduled inservice day. In this workshop, every teacher might get a few minutes of hands-on experience, see some computers and their applications, and be exposed to general ideas of computers in education. If this initial workshop is to be effective, there must be some follow-up activities. These might include visits to the teachers' schools by a computers in education resource person, placing computers in teachers' classrooms, and classroom visits by school administrators.

However, an introductory workshop barely scratches the surface of the computers in education literacy teachers need. Unfortunately, relatively few school districts have a coherent plan for higher level inservice work. Indeed, many teachers fail to see this need. At a recent one-day introductory workshop, a teacher complained to me that the workshop was not meeting her needs. It turned out that this was the sixteenth introductory workshop she had attended!

My feeling is that every inservice teacher should have an opportunity to take two full courses.

1. **Introduction to Computers in Education.** While this course has substantial hands on experience, the amount of actual computer programming in the course would likely be in the range of 15 to 25 percent.
2. **Introduction to Computer and Information Science for Educators.** The majority of this course would be an introduction to problem solving and programming.

Each of these would be a four-credit quarter-length course or a three-credit semester-length course. While the courses could be independent of each other, the first would be the preferred course for a person taking only one.

In my opinion, courses 1 and 2 are only a beginning for a teacher who wants to be a building level specialist or a teacher of computer and information science. I feel that all inservice teachers should have easily available opportunities to take higher level courses. Building upon courses 1 and 2 as a prerequisite, a district might work with nearby colleges and/or use its own resources to offer courses in areas such as:

1. Design of computer-assisted learning materials.
2. Programming languages (BASIC, Logo, Pascal).
3. Applications of computers to the ________ (fill in the blank with any secondary school subject) curriculum.
4. Computer graphics.
5. Artificial Intelligence.
6. Modeling and simulation.
7. Information retrieval.
8. Etc.

The list is easily extended. The point is, there are literally dozens of appropriate courses above the introductory level. Many teachers would take these courses if they were readily available. This issue lists colleges where such summer courses are offered. Teachers who take these courses will become the building level resource people and the teachers of computer and information science. Such courses are essential if computers are to have a positive effect upon our educational system.

Computer Literacy: Talking and Doing

(Reprinted and edited slightly from TCT Vol 10 #8, April 1983)

The U.S. Office of Education has funded a national project to define computer literacy and to develop an instrument that could be used to measure the computer literacy of students, teachers, principals and superintendents. The Educational Testing Service of Princeton, New Jersey is the prime contractor on this project and the Human Resources Research Organization of Alexandria, Virginia is a subcontractor for a major piece of the work.

In January 1983 a distinguished group of "national experts" met in Washington, D.C. to express their opinions on ideas going into the development of the definition and measurement instruments. I found the meeting both enjoyable and frustrating.

The essence of the problem is defining computer literacy. The group of nine national experts seemed to divide into two camps. One camp essentially thinks of computer literacy as a talking-level of knowledge. This includes knowing some computer history; knowing definitions of computer-related words, knowing some applications of computers in business, government and industry; knowing about social and ethical issues; and so on. Many of these objectives are stated, "The student is aware of . . ." Of course this talking-level-of-knowledge camp wants students to have some hands-on computer experience and hence a modest level of skill in actually using a computer.

The second group admits that the ideas of the first group are important, but insists that the most important aspect of computer literacy is being able to make a computer *do* things. This group then is further divided as to what this might mean. Does it mean being able to program in Logo, BASIC or Pascal, or does it mean knowing how to use a word processor, an information retrieval system and an electronic spreadsheet?

Those of you who know me personally or who have followed my writings are aware that I support both groups, but most strongly support the "doing" parts of a definition of computer literacy. Within that group I am moderately supportive of the "traditional language computer programming" subgroup and very strongly supportive of students learning to use applications packages.

I believe that we are at a critical junction. If the "talking-knowledge" definition wins out, it will be a substantial setback to the progress of computers in education. Imagine if a talking-knowledge group won out in reading and writing literacy or in mathematics literacy. Students would not have to be able to read, write or do mathematics. Rather, we would assess their literacy (presumably via oral testing) by determining if they knew some applications of reading, writing and arithmetic. We would determine if they had some historical knowledge of these areas, had seen and touched a book, had been read to from a book, and so on. I suppose that the ethics of book stealing would be discussed, as would be the threat to privacy of actually using books to store information about people.

All of this is silliness, of course, as is limiting computer literacy to a talking level of knowledge. I believe the major issue will be the question of programming versus using applications packages within the "doing" group. I am quite experienced in arguing that all students should receive instruction in computer programming. Such instruction is an excellent vehicle for learning and practicing important ideas such as problem solving, top-down problem analysis, representation of algorithms, algorithmic thinking, repetition, modularity, bugs and debugging, documentation. My fear is that the typical teacher of computer programming may treat these topics as incidentals and produce "hackers" instead of computer literates.

At the current time I support the teaching of computer programming at any grade level, provided the teacher is competent in the computer field—that is, has a good knowledge of all of the ideas listed in the previous paragraph and integrates them into the instruction, that the instructional materials have these same characteristics, and that the totality of hardware and software available are adequate to support this type of instruction

Unfortunately, this seldom occurs. The basis for my strong support of students learning to use applications packages is that less teacher knowledge and less high-quality instructional materials are needed. Moreover, this is clearly the sense of direction of the computer field. The computer-using public of the year 1990 or 2000 will not know a programming language such as Logo, BASIC or Pascal. Their ability to use computers will not depend upon knowing how to program in these or other high-level programming languages.

What *will* be important is knowing how to utilize the capabilities of a computer and integrating this knowledge into one's overall knowledge and performance. The student who knows how to write will know how to use a word processor as an aid to writing. The student who knows how to read will know how to use a computerized information retrieval system to obtain materials to be read. The student who knows the meaning and use of equations or graphs will know how to use a computer to solve equations and draw graphs. The student interested in composing music will know how to use a computer-assisted music composition and performance system. All students will learn to use electronic spreadsheets and other general-purpose aids to problem solving.

I believe that this is the key to computer literacy. It is a "doing" level of knowledge, with this knowledge integrated into the totality of a student's knowledge and performance. This type of computer literacy can be taught now and can be measured. I believe that it is essential that those who would define and measure computer literacy see that this is where we are headed and that this must be a significant part of any modern definition of computer literacy.

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.

Batch processing

An approach to data processing where a number of similar input items are grouped for processing during the same machine run. It is generally associated with one person using a computer at a time, as contrasted with timeshared computing.

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

Byte

One character (digit, letter or punctuation mark). The storage capacity of a computer is often stated in bytes. The primary storage of an inexpensive microcomputer may be 16K bytes (K = 1024) while a large disk pack may provide a billion bytes of secondary storage.

Calculator

An electronic digital machine designed to carry out arithmetic operations such as addition, subtraction, multiplication and division. More expensive calculators tend to have many computer-like features, and there is no exact dividing line between calculators and computers.

***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

An electronic digital machine designed for the input, storage, manipulation and output of alphabetic and numeric symbols. It can automatically and very rapidly follow a detailed step-by-step set of directions stored in its memory. (See *hardware* and *software*.)

***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* (CAL)**

Any use of computers to assist in the overall tasks of instruction and learning.

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. CMI is frequently included as part of CAI.

Computers in education

This field is often divided into administrative uses, instructional uses and research uses. Higher education expends about three to four percent of its budget in use of computers, with funds nearly evenly divided among the three categories. Computer usage in pre-college education is at a much lower level, with the bulk of current use being administrative in nature. However, instructional use of computers at this level is growing very rapidly.

Courseware

A combination of software, print materials and other aids for the student and teacher.

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.

Instructional computing

The field of instructional use of computers is often divided into three parts: teaching using computers, teaching about computers, and the study of the impact of computers upon the current curriculum.

Interactive computing

Many computer systems are designed so that the person using the machine can interact with it while a problem is being solved. This interaction is usually by means of a typewriter-style keyboard terminal, although other modes (such as by voice) are also possible. In an interactive system there can be a continual two-way flow of information between the computer and the computer user during the process of solving a problem.

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 and others 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.

Modeling and simulation
A model is a representation of certain key features of an object or system to be studied. Scientific models often make use of complex formulas and involve substantial use of mathematics. If a computer is used to solve the equations and carry out the necessary calculations, the process is called a computer simulation. Modeling and simulation are essential tools in every area of science, as well in economics, business and a number of other fields.

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

Programming language
Each computer is constructed to be able to follow (execute) a program in its "machine language." The machine language for a particular machine consists of perhaps 60 to 300 different instructions, and different makes or models of computers tend to have different machine languages. There are a number of more universal, high-level computer languages that people have developed such as BASIC, COBOL, Logo, FORTRAN and Pascal. Each such language is designed to be particularly useful to a specified group of people. For ex-

ample, COBOL is designed for use in business, and BASIC is a student-oriented language. A particular computer can use one of these languages only if a translating program has been written to translate statements from the language into the computer's machine language.

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.

Timeshared computing

A form of interactive computing in which a number of terminals are connected to a single computer system and share its resources. The system can be designed to allow easy communication among the users Typical applications are airline and motel reservation systems, stock market quotation systems, and multi-user interactive instructional computing systems

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 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 5 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.

2. 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.

3. *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.

4. *The Computing Teacher*, 135 Education, 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.

5. *Creative Computing*, 39 E. Hanover Ave., Morris Plains, NJ 07950. ($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. ($25 for 10 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. ($31 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. (Free journal.)

    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.

ICCE also publishes:

The Computing Teacher Magazine .... 9 issues $16.50
Non-U.S. $20.00

An Introduction to Computing:
Content for a High School Course $2.50

Teacher's Guide to Computers in the Elementary School $2.50

Precollege Computer Literacy:
A Personal Computing Approach $1.50

Evaluator's Guide $2.50

Introduction to Computers in Education for
Elementary and Middle School Teachers $7.00

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A Teacher's Guide Book.............................. $2.50

Computer Technology for the Handicapped in Special
Education and Rehabilitation: A Resource Guide $7.00

Parent's Guide to Computers in Education $3.50

Microcomputers in the Classroom—Dreams and Realities ... $3.50

Computer Literacy Activities for Elementary
and Middle School Students $3.00

Topics: Computer Education for Colleges of Education $9.00

Logo Lessons: Ideas for the Classroom $11.00

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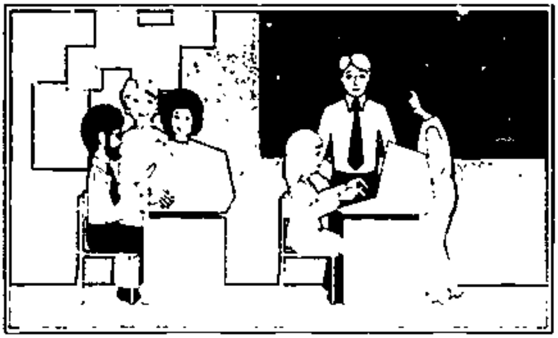

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INTRODUCTION TO COMPUTERS IN EDUCATION FOR ELEMENTARY AND MIDDLE SCHOOL TEACHERS by David Moursund. $7 on prepaid orders to ICCE. This 8½ x 11, 96-page book, published Fall 1981, is an easy to read introduction to computers in education. It is designed 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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