I recommend this project for acceptance by the Honors Program of Ball State University for graduation with honors.

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Computers in the Elementary School

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Table of Contents

Chapter

I. A Brief History of Computers ........................................... 3

II. Operation of the Computer ............................................. 9

Definition of Terms ....................................................... 9

Types of Computer Systems ................................................ 11
Drill-and-Practice ......................................................... 11
Tutorial System .............................................................. 12
Dialogue System ............................................................. 13
Calculator System ............................................................ 13
Management System .......................................................... 14

III. Experiential Studies with Computers in the Elementary School .......... 15

At Stanford .................................................................. 15

INDICOM .................................................................... 26

At Indiana University ....................................................... 28

PLAN ........................................................................ 28

IV. Advantages .................................................................. 34

Advantages for the Students .............................................. 34
Advantages for the Teacher ............................................... 36
Advantages for the Administration ...................................... 37

V. Disadvantages ................................................................ 38

Cost .......................................................................... 38

Programs ...................................................................... 41
A Brief History of Computers

To many, the use of computers in education is a relatively new and/or controversial idea. However, although computers were almost non-existent in education before 1963, some educators of the past have proclaimed the needs for their use. S. L. Pressley of Ohio State University stated:

The average teacher is woefully burdened by the routine of drill and information-fixing. It would seem highly desirable to lift from her shoulders as much as possible of this burden and make her freer for those inspirational and thought-stimulating activities which are, presumably, the real function of the teacher. (39:18)

Saying this, Pressley introduced his plan for a machine that would "teach informational and drill material more efficiently, in certain respects, than the human machine." (39:18)

Just as the use of computers in education is not a new idea, neither is the use of devices to count or calculate. It is not actually known when man began to record or calculate his possessions. Some people believe that the scratches found on cave walls are actually records of the number of sheep in a man’s flock or the number of bundles of grain that he had. Other historians surmise that stones or pebbles were also used to count animals and grain since the modern word "calculate" is derived from a Latin word that means "stone" or
"pebble." (40:198) The fact that the word "digit" is used when discussing parts of numerals, as well as parts of hands, indicates that the fingers were (and still are) used as computational aids. (40:198)

The abacus, man's first device to express specific quantities, was invented about 2,000 years ago. (5:121) The abacus, which "may be the most efficient computation device, in terms of investment in equipment and ease of manufacture compared to the extent of computing aid obtained, that man has ever invented," originated in China and the Near East. (40:198)

The first abacus was probably nothing more than lines drawn on the ground with stones used to indicate amounts. (5:121) Gradually, modifications were made.

Beads, sliding on wires, substitute for the pebbles. Five beads below a wooden bar are units; each bead above is worth five. Numbers are represented by pushing beads against the bar. The wires or columns, starting at the right, represent place value: units, tens, hundreds, etc., just as our decimal arithmetic columns do. (34:11)

Few improvements were made in calculating machines until the seventeenth century. In 1624, at the age of 19, Blaise Pascal of Rouen, France, invented a calculating
The calculator, which was about the size of a shoebox, was a gear-driven machine that could be operated by moving a series of wheels. (5:121)

Addition and subtraction could be performed on this machine. The calculator proved very useful for the purpose for which it was designed—to help Pascal's father, a tax collector, figure his accounts. (5:121)

In 1671, Gottfried Wilhelm Leibniz, started to improve Pascal's calculating machine. He developed a machine that would multiply (by repeated addition) and divide. This machine was built in 1694. (34:3)

No further improvements or advancements were made until the beginning of the nineteenth century. At this time, Joseph M. Jacquard decided to develop a system to control weaving patterns on a loom (40:198) Holes were punched in cards and a series of cards was used to control the machine. (34:3)
Charles Babbage, an English mathematician, designed a "difference engine" in 1822 that contained "most of the basic elements of the modern general purpose computer." (40:198)

From his work on the difference engine, Babbage got the idea for the following machine.

Powered by steam, it would work from a planned program of operating instructions stored on punched cards. It would include, as our modern computers do, a memory or store, an arithmetic unit, a section for entry of data or instructions, and an output section for printing results. It would also perform decision-making functions. (34:4-5)

Even though Babbage persuaded the British government to give him some money for his experiments (about $1,000,000 by today's standards), he was unable to develop this machine. (40:199) Unfortunately, it was so long before more work was
Information from the 1890 United States census was sorted and classified by a computer developed by Dr. Herman Hollerith. (40:199) This computer could tabulate information that had been recorded by punching holes in cards which were positioned over mercury-filled cups. When a lever was pulled down, a set of spring-loaded pins was pressed against a card. "Where there is a hole, a pin dropped through into the mercury and made an electrical circuit. This electrical circuit, in turn, caused a pointer to move one position on a dial-and
in this way added another digit to the unit." (5:121)

Hollerith's computer was able to tabulate the census in about one-half the time it took to handle the census in 1880. (34:5)

It was not until 1937 that the next major advancement was made. At this time, Howard H. Aiken of Harvard University designed a computer composed of "seventy-eight adding machines and desk calculators controlled by a player-piano-type roll of perforated paper." (5:121) International Business Machines became interested in Aiken's computer and offered to help him develop the Automatic Sequence Controller, or Mark I. (40:99)

The Mark I could perform 23-digit additions and subtractions in three tenths of a second and could multiply two 23-digit numbers in about six seconds. ...Once the Mark I was started on the first instruction in a program, no further human direction was needed until a new problem was fed in the machine. (34:6)

The Mark I, which was built in 1944, was placed on display at the Smithsonian Institute in 1964. (7:7)

The first all-electronic digital computer, the ENIAC (Electronic Numerical Integrator and Calculator), was
developed during World War II and was completed in 1946. (40:199) Graduate student J. Presper Eckert and physicist Dr. John W. Mauchly developed the ENIAC at Moore School of Electrical Engineering of the University of Pennsylvania. (34:5)

They eliminated the need for mechanically moving parts, such as electrically controlled counter wheels, to represent digits and numbers. Instead, they adapted electronic flip-flop circuits and used electronic pulses to flip vacuum tubes on and off like switches, with the "on" and "off" states representing numbers. Since electronic pulses could move thousands of times faster than electro-mechanical devices, the concept behind ENIAC was a real breakthrough in the development of more efficient calculators. (34:5)

Dr. John von Neumann is credited with the next advancement idea. He felt that the computer would be more efficient if operating instructions, as well as data, could be stored in the computer's memory. (34:6)

This idea makes it possible for the programs to cause the machine to make internal modification to the program while the machine is running, and this internally modifiable, stored-program concept has been in many ways the most revolutionary development in the history of machines. (40:169)

The first machine to use Neumann's idea was the EDSAC (Electronic Delay Storage Automatic Computer) which was developed at the University Mathematical Laboratory, Cambridge, England. (40:200) It was followed by the EDVAC (Electronic Discrete Variable Automatic Computer). Perhaps the most famous computer of the 1950's was the UNIVAC. The UNIVAC "forecast the results of the presidential election before all the votes had been counted." (7:7)
Men continued to work to improve computers in size, speed, and efficiency. When the first computer was placed on the commercial market in 1950, few businesses could afford them. Now most businesses feel that they cannot afford to do without them.

Businesses are not the only ones to see the need and possibilities for the use of computers. Many educators now express a belief in the advantages of computers in education. Educators have been searching for a way to individualize instruction. At one time, great hope was placed in Programmed Instruction. When the shortcomings of Programmed Instruction became evident, these educators turned to computers. (12:6) How useful the computer will be in education remains to be seen.
Operation of the Computer

Definition of Terms

In order to better understand the information presented in this paper, knowledge of the following definitions will be helpful.

1. Computer-assisted Instruction (CAI)--The pupil is faced with the computer and works directly with it. The computer teaches, or administers the pupil's instruction. (14:351)

In computer-assisted instruction terminals located in the school, classroom, or home may be connected by telephone lines to the central processor. The central computer may be located at a nearby university or business, or the processor may be at an institution more than a thousand miles away.

In its simplest form, a computer-connected typewriter can provide drill materials to students in subject areas such as arithmetic and spelling. The materials can be logically sequenced and presented to a student on the basis of his past performance in a manner that insures continuous feedback.

In its most sophisticated form, material can be presented in a variety of modes (e.g., printed, audio, visual, graphic). A variety of response modes are available (e.g., written, typed, response selection, audio, light pen). (12:14)

Another type of computer system is

2. Computer-managed Instruction (CMI)--The computer helps the teacher. It comes into the instructional program behind the teacher and serves as an aid. In computer-managed
instruction the computer assists the teacher; it does not instruct the pupils as in computer-assisted instruction. (14:352)

In CMI the pupil does not come in contact with the computer. The computer is used to keep a record of the student's performance. The teacher uses this information to plan a better, more individualized course of study for each student.

When talking about the computer one often hears about problems related to hardware and software. The first item is

3. Hardware--The mechanical, magnetic, electric, and electronic devices from which a computer is constructed; or the computer itself as contrasted with its programs and programming system. (40:194)

The second component, and perhaps the most important and difficult to produce, is

4. Software--The collection of man-written solutions and specific instructions needed to solve problems with a computer. (also) All documents needed to guide the operation of a computer, e.g., manuals, programs, flowcharts, etc. (34:89)

The cost of computer hardware and software is so great that most schools and/or small businesses can not afford to have their own computers. They must rely on

5. Time-sharing--(it)...conserves the user's time and enables many people to share the processing power of a single computer and work out individual problems during the same time span. (34:16)

A number of schools and/or businesses share time on the computer and divide the expense. Each location is equipped with terminals through which the user communicates with a computer. (34:16)
Types of Computer Systems

Drill-and-Practice

At the simplest interaction level are those systems that present a fixed, linear, sequence of problems. Student errors may be corrected in a variety of ways, but no real-time decisions are made for modifying the flow of instructional material as a function of the student's response history. Such systems have been termed "drill-and-practice" systems... (4:225)

In the drill-and-practice system, the teacher presents new material. She guides the students in their understanding of the material before they attempt to use the computer. When the teacher is about ready to move on to new material, she will refer the students to the computer for further work.

A normal practice at the computer would go something like this: The teacher would program the computer by giving the grade, the code number of the task for the day, the number of the day spent on the task, and the level of difficulty. The child would go to the console and type out his name. The computer, which has the pupil's name stored in its memory, would select the work for the day. A problem would then be presented to the child. Depending upon the type of computer, the child could either record his answer by touching a light-pen to a television screen, by typing on a typewriter keyboard, or by speaking into a microphone. If the correct answer were given, the next problem would be presented. If the response were incorrect, the word "wrong" either would appear on the screen or be spoken by the computer. The problem would then be repeated. If the answer were still wrong, the
correct answer would be given, and the problem would be
repeated. After each problem was given, the child would have
only ten seconds in which to make his response. If the child
did not respond in this length of time, the computer would give
the correct response and go on to the next problem. When the
lesson was completed, the machine would print out the following:
total errors, problems missed (their numbers), and the total
elapsed time in seconds. If the child scored above eighty
per cent, he would advance to the next level. If he scored
below sixty per cent, he would revert to the next lower level
on the next lesson. At the end of the day the teacher would
type the word "Finished." The computer would then give her
the following: the number of students who made time-outs and
ersors on each problem, the distribution of error for the
entire class, and the distribution of the total elapsed time
on the lesson. The teacher could then study the result and
work on special difficulties with individual students.
(Additional information will be discussed in the section on
computers at Stanford University.)

**Tutorial System**

Under the tutorial system the computer would try to
teach a concept and would initiate question for the student
to answer.

Tutorial programs have the capability for real-
time decision making and instructional branching
contingent on a single response or on some subset of
the student's response history. Such programs allow
students to follow separate and diverse paths
through the curriculum based on their particular
performance records. The probability is high in a tutorial program that no two students will encounter exactly the same sequence of lesson material. However, student responses are greatly restricted since they must be chosen from a prescribed set of responses, or constructed in such a manner that a relatively simple test analysis will be sufficient for their evaluation. (4:225)

Dialogue System

Another system that is being developed is the dialogue system. The child would ask the computer a question, and the computer would verbally answer the question. This system requires the computer to have a large store of knowledge in its memory and also to recognize the spoken word.

At the other extreme of our scale (starting with the drill-and-practice, the tutorial, ...) characterizing student-system interactions are "dialogue" programs. Such programs are under investigation at several universities and industrial concerns, but to date progress has been extremely limited. The goal of the dialogue approach is to provide the richest possible student-system interaction where the student is free to construct natural-language responses, ask questions in an unrestricted mode, and in general exercise almost complete control over the sequence of learning events. (4:225)

Calculator System

The computer is used merely for computations in the calculator system. The student might be given a problem in which he is asked to add 1, 1/3, 1/3, 1/3, and 1/15. Instead of having to find the least common denominator and progress from there, the student merely uses the computer to perform the computations. Thus, more stress is placed on mathematical knowledge than on computational skill.
Management System

Under a system similar to the computation system, the computer is used for school management. The computer is used for such tasks as: making out payrolls, setting up class schedules, and arranging bus routes.
Experimental Studies with Computers in the Elementary School

Many people have been concerned about the value of computers in the elementary school. To determine the merit of these computers, research programs were initiated. Of course, a large sum of money for each program was needed. This money came partly from business concerns, but mainly from the United States Government.

Over 100 research-related projects dealing with educational uses of computers have been funded under the Cooperative Research Act, amended by Title IV of the Elementary and Secondary Education Act, and Title VII of the National Defense Education Act. Of these, about two dozen current projects relate to computer-assisted instruction for use in schools and colleges. (42:24)

The following are summaries of some of these projects.

At Stanford

One of the first groups to begin a program of computer research was the Institute for Mathematical Studies in the Social Sciences at Stanford University in January of 1963. The Carnegie Corporation of New York supplied the funds for the first five years of the program, (31:1) and the National Science Foundation helped to supply additional funds. A computer-based laboratory, in operation since December, 1963, was constructed. (31:1)
The initial instruction system in the Institute consisted of a medium-sized computer and six student stations placed within 100 feet of the computer. Each student booth contained two visual-display devices. The first was a random-access optional-display device developed for the laboratory by IBM Corporation that presented microfilmed source material on a 10-inch by 13-inch ground-glass screen. It was possible to encode the equivalent of a 512-page book (8½-inch by 11-inch standard page) on microfilm and any page or one-eighth of a page could be displayed randomly within 1 second. The student responded to the display by using a light pen on the face of the screen itself. As the pen was touched to the screen, the coordinates of that position were sent to the computer for comparison with any predesignated areas of the screen. The accuracy of the light pen permitted identification of a ½-inch square on the screen. This device, which was the predecessor of the IBM-1500 system mentioned below, has been phased out and is no longer in the Institute.

The second display device, which is still in use, was developed for the Institute by the Philco Corporation. It is a cathode-ray tube, commonly called a "scope." It can display points of light in an area 10 inches high by 10 inches wide with 1,024 possible positions on both the horizontal and vertical axes. In addition to individual points, 120 prearranged characters may be displayed in five different sizes. It is also possible to display vectors by simply identifying the end points. A typewriter keyboard is attached to the scope and may be used to send information from the student to the computer.

An audio system designed by Westinghouse Corporation can play prerecorded messages to the user through individual speakers in each student booth. The messages are recorded on magnetic tape 6 inches wide; two tape transports may be assigned to each of the six stations. Each transport has a capacity of about 17 minutes, which can be used in any combination (e.g., from one message 17 minutes in length to 1,020 messages of 1 second each). The random-access time to any stored message is approximately 1 second. For a number of technical reasons, this equipment is no longer in operation in the laboratory.

Until June, 1968, the central computer was a PDP-1 designed by Digital Equipment Corporation. It has a 32,000 word core and a 4,000 word core, which can be interchanged within the 32 bands of a magnetic drum on files stored on two IBM-1301 disks. (The two IBM-1301 disks were replaced by the two IBM-2314 disks in the fall of 1968, and a PDP-10 has become the main computer, although the PDP-1 is still in operation.) (31:1)
During the latter part of 1963 and in 1964 the Institute conducted various trial runs on the computer. These lessons involved only a few children, each practicing on different drills. In the spring of 1965 the computer was used in a classroom situation.

By remote control, 41 fourth grade children were given daily arithmetic drill-and-practice lessons on a teletype machine in their classroom at Grant School in the Cupertino Union School District (April 19 to June 4, 1965). This installation constituted an important first step in moving terminals from the Stanford campus to elementary schools, with direct connection from the computer to the terminals by telephone lines. (31:3)

During the years 1965 to 1969 the Institute continued to expand its program. In 1965, the program grew to include drill-and-practice teletype programs at three schools. Some terminals were located in Kentucky in 1967. By the end of 1968 the drill-and-practice mathematics program had branched out to include terminals in California, Iowa, Kentucky, Missouri, and Mississippi. (31:6) In May, 1969, another advancement was made in the program.

On Monday, May 18, and Friday, May 22, the Institute made what is perhaps the first use of a communication satellite to distribute CAI. The demonstration was important because it proved that satellite distribution of CAI through low-cost satellite ground stations has the potential for making CAI as accessible to isolated rural areas as to the large cities. (31:9)

The configuration for the Stanford CAI System as of June, 1969, is shown on the following page. Since June, 1969, a few of the locations have dropped out of the Stanford Program to develop programs of their own.
The Institute at Stanford University has done research on drill-and-practice and tutorial computer systems in many subject areas. A list of some of these programs is contained in the table on the following page. The system that has received the most attention is the drill-and-practice system in mathematics.

The drill-and-practice program began in 1965 when 41 fourth-grade children were given drills on a terminal in their classroom. (51:2) By the 1968 school year the program had expanded to include about 2,500+ students in California, Mississippi, and Kentucky. (51:2) In this program the teacher would introduce the children to the material before it was presented at the terminal.

The content material was arranged in blocks. The material for these blocks was similar to the material presented at that grade level in several texts. Samples of problems presented in some blocks are shown on page 21. The seven days that were required to complete each block were arranged as follows: day 1, pretest; day 2 to 5, drill and review drill; day 6, drill and review posttest; day 7, posttest. (51:10)

"For each day of drill, five drills, one at each of the five levels of difficulty, were prepared; a total of 25 drills per block." (51:10) Several review drills were also prepared for each level of difficulty. In this "block" system each child worked at his own ability level; however, each student covered the same number of topic areas.

The following is an example of the drill-and-practice method of teaching mathematics in the elementary school.
<table>
<thead>
<tr>
<th>Program</th>
<th>66-67</th>
<th>67-68</th>
<th>68-69</th>
<th>69-70</th>
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</thead>
<tbody>
<tr>
<td>Drill-and-practice mathematics</td>
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<tr>
<td>Grades 1-8 (block structure)</td>
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<tr>
<td>California</td>
<td>1,500</td>
<td>1,441</td>
<td>2,475</td>
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<td>Iowa</td>
<td>640</td>
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<td>Kentucky</td>
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<td>1,632</td>
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<td>Mississippi</td>
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<td>640</td>
<td>2,113</td>
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<td>Ohio</td>
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<td>101</td>
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<td>Washington</td>
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<td>92</td>
<td>159</td>
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<tr>
<td>College level</td>
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<td>Tennessee (algebra)</td>
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<td>183</td>
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<tr>
<td>Tutorial primary-grade mathematics</td>
<td>53</td>
<td>73</td>
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<td>Tutorial reading, Grade 1</td>
<td>50</td>
<td>88</td>
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<td>Drill-and-practice in initial reading</td>
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<td>Grades 1-3, Remedial 4-6</td>
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<td>442</td>
<td>642</td>
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<td>Language Arts</td>
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<td>Drill-and-practice mathematics</td>
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<td>Grades 1-6 (strands structure)</td>
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<td>California</td>
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<td>Ohio</td>
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<td>Washington, D. C.</td>
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<tr>
<td>Tutorial computer programming</td>
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<tr>
<td>Tutorial logic and algebra</td>
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<tr>
<td>Grades 4-8</td>
<td>76</td>
<td>195</td>
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<td>459</td>
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<tr>
<td>Tutorial problem-solving</td>
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<tr>
<td>Grades 5, 6</td>
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<tr>
<td>First- and second-year Russian</td>
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<td>GRADE</td>
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<td>9 + 1 = 5 + ---</td>
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<td>9</td>
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<td>3 + 8 --- 9 + 4</td>
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<td>6</td>
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<td>(17 X ---) + 9 = 28722</td>
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"Fig. 1. Samples of problem formats for grades 1 through 6, drill-and-practice program."
Each student responded to problems presented on a teletype located in the school. The model-33 teletypes were connected to the PDP-1 computer at Stanford by means of telephone lines. After the student had signed into the program by typing his assigned student number and his first name, the teletype printed his last name and presented the appropriate set of problems. The pace of the program presentation was determined by the student's response rate.

The teletype printed each individual problem and positioned itself in readiness to accept the answer in the appropriate place. The student typed in the answer. If his answer was correct, he proceeded to the next problem. If he gave the wrong answer, the teletype printed NO, TRY AGAIN and presented the problem again. If he made a second error, the teletype printed, NO, TRY ANSWER IF... and presented the problem once more. If the student gave the wrong answer for the third time, he was given the correct answer and the teletype automatically proceeded to the next problem. The student was allowed from 10 to 40 seconds to respond, depending upon the type of problem presented.

If a student took more than the allotted time to give his answer, the procedure just described was followed, but the teletype printed TIME IS UP, TRY AGAIN in place of NO, TRY AGAIN.

The level of difficulty of the first day of drill was determined by the student's performance on the pretest... The level of difficulty of each successive drill in the same concept block was determined by the student's performance on the preceding day's drill. Thus, if the student's performance on a drill was 80 per cent or greater, his next drill was one difficulty level higher. A score of less than 60 per cent branched him down a level for the next drill. If the score was between 60 and 80 per cent, the student remained at the same difficulty level for the next drill. (50:243-350)

Although each child on the same difficulty level of a task was given the same drill content, the content of the review drill varied according to the pupil's past performance on specific concept blocks. The student's review drills were chosen in accordance with the concept block posttest score that was the lowest. The difficulty level, which remained
constant for the four days of drill, was determined by the posttest. (41:13)

In order for the student to be able to change difficulty levels throughout the drills, a branching process was designed for the computer. A diagram of the branching system for drills and review drills is found on the following page.

The results of the drill-and-practice programs are very encouraging. In the programs reported so far, the experimental groups have achieved more than those students in the control group. The drill-and-practice system seems to be very effective in helping those students in school environments that are not "educationally and economically affluent." (51:53)

Another computer system that the Institute has worked with is the tutorial system. Under the tutorial system the information is presented only by the computer. The children respond to questions by use of the typewriter keyboard or light pen. The following is a description of a tutorial lesson.

The students received their programmed instruction in a room which contained 17 student stations and a proctor station for use by one teacher on duty. The student stations were separated by four-foot partitions that extended far enough from the walls to provide a degree of privacy for the students. When the children arrived in the student station room, they looked for their names on the CRT screen at their assigned stations, put on their headsets, and started their program by touching the light pen to a smiling face displayed on the CRT. After the allotted time for the class, approximately 20 minutes, the students were signed off automatically as they completed their current lesson and the message YOU HAVE BEEN SIGNED OFF appeared on the CRT. The children entered an
Fig. 2. Branching structure for a seven-day concept block.

*n-a Block with lowest posttest performance.
adjacent classroom and joined a teacher who escorted them back to their classroom.

Both explanatory and practice problems contained provisional audio messages that were heard only by the students who responded incorrectly or who failed to respond within a reasonable time. For example, for one problem, a drawing of a car and a drawing of a truck surrounded by set braces and followed by an equal sign was presented on the CRT; this problem was accompanied by the audio message "There are two members in this set." After this message, two more sets, one empty and one containing a train and a steamshovel, each preceded by a box, were displayed below the initial set; the choices were accompanied by the audio instructions, "Find another set with two members." At this point a small "X" (for pen) was displayed in the corner of the CRT as a signal to the student to respond. If the student touched his light pen to the box in front of the correct choice, a smiling face was displayed and he heard, "Yes, the sets have the same number of members," and presentation of the next problem began.

If the student did not respond within 10 seconds he heard, "Which set below has two members?" If the student responded incorrectly, he heard the audio message, "Point to the box next to the set with two members," and saw a sad face. For most problems in the curriculum, students were allowed three chances to produce the correct answer. After three incorrect responses, a brief audio message accompanied the display choice. (51:28-29)

If a student did very well on the first part of a lesson, he could skip to the next lesson. If he did poorly, he was branched to a remedial lesson. If he still did poorly, the proctor was signaled to help the student.

One of the main differences between the drill-and-practice system and the tutorial system is the amount of time spent on a concept. In the drill-and-practice system, no matter how well a child understands a concept, he spends seven days working on the concept. In the tutorial program the student can spend as little, or as much, time as he needs on a
specific concept. Thus, one child may cover 50 concepts in a year, while another covers only 10.

As of yet, the tutorial program has not been as effective as the drill-and-practice program. It has had its best results with the low achievers. Because the tutorial program is newer than the drill-and-practice program, time and experimentation may help improve this method of instruction.

INDICOM PROJECT

INDICOM (an abbreviation for individualized communication) became the first public school CAL project in the midwest after Don C. Tatroee, Superintendent of Waterford Schools in Pontiac, Michigan, began to wonder if computers could be used to improve instructional methods. (41:1) The INDICOM program, funded by Title III, Elementary and Secondary Act of 1965, was started at Riverside Elementary School in grades two through six. When the program first began, the computer terminals were connected to an RCA Spectra 70/35 computer in Palo Alto, California. Later, the terminals were connected to the RCA Instructional/71 System in the school district. This system was composed of an RCA 70/35 Central Processing Unit, 65 K Bytes, and two disc drives—seven and a quarter million characters each. (41:9) The programs, or curriculum, for this computer were written by the teachers in the Waterford School District.

The drill-and-practice computer system was used in the INDICOM project. The operation of this drill-and-practice computer was similar to that at Stanford, with the idea that the student achieve success. "...a rule of thumb is that 90%
of the items." (44:2) Dr. Robert W. Scrivens, Research and Mathematics Specialist with the INDICOM project, has this to say about the drill-and-practice program in mathematics:

CAI mathematics drill and practice purports to furnish teachers and students with systematic, short, and successful means of building and retaining computational skills. A daily drill and review via CAI of from three to ten minutes per student indicates from this study, at least, that significant differences are made in achievement as measured by a standardized test.

The most important point for classroom instruction may be that short drills and reviews geared to an individual student's needs, where each student achieves success for himself, and is not compared to or competing with other students, accomplishes at least as much as traditional instruction for the less bright student, and definitely accelerates the more able students. (44:5)

Through research and evaluation, the project workers feel that INDICOM has demonstrated the following:

- the ability to manage a major innovative project through conception to implementation-reporting evaluation data fairly and accurately.
- achievement in mathematics and language arts can be extended and accelerated by CAI. This fact has been documented by testing in the elementary and high school levels. The summary of the math evaluation data clearly shows significant gains at all levels.
- student attitudes towards mathematics and language arts improves when CAI is utilized.
- students continuing interest in CAI indicates that the improved performance is due primarily to the personalization of instruction, that is afforded through CAI, rather than the initial impetus provided by the hardware.
- teachers who apply the logic of the systems approach to CAI design appear to exhibit a more positive attitude toward teaching and learning in general; that is teachers are more inclined to view teaching and learning in a cause and effect relationship.
- there is sufficient subjective data to indicate that CAI is particularly appropriate for youngsters classified as handicapped learners, specifically the deaf and mentally retarded.

the curriculum design work in the project has had significant impact upon the school district as a whole. The employment of the systems approach to curriculum development and the use of systematic management techniques...have been widely disseminated in the district to the ultimate benefit of all students in the school system. (41:5-7)

From these conclusions, it is evident that the Waterford School District is happy with the INDICON project. However, there have been some problems with the project. There have been some problems with the RCA/91 computer, but it is believed that these will be alleviated. The major problem is one of funding.

The government has cut back on its appropriations to the INDICON project. At the present time, the number of people on the school’s staff has been cut almost in half. The project also owes RCA a final payment on the computer ($152,650.00). (41:15) To continue research and development, the project must have “a minimum of $70,000 for operation per year to a maximum of $150,000, a year for (a) regional center.” (41:16) The future of this project rests on its ability to obtain funding.

At Indiana State University

Another drill-and-practice program in mathematics is in operation at Indiana State University. The computer programs have been used in both Indiana State’s laboratory school and in the Wabash Valley School District. In this computer program the students are presented with random exercises. The IBM 1130 computer provides appropriate material in
accordance with the student's response. The personnel at
Indiana State have been doing research on how student errors
and misconceptions can be corrected through feedback. The
findings of this research will be available at a later date.

The computer system's goal is not only to improve instruc-
tion, but to help improve training programs. Not only do
students benefit from the program, but also faculty members
gain skill in the operation of CAL equipment.

PLAN

Unlike the other projects that have been mentioned,
PLAN (Program for Learning in Accordance with Needs) uses a
computer-managed system instead of a computer-assisted system.

The student does not interface directly with
the computer, nor does the computer actually administer
or teach the student any of his instructional program.
Student-teacher interaction is maintained in the
classroom and the computer is used only as an aid to
the teacher. The computer becomes an informational
system which records the student's learning and academic
history and his program of studies, scores the tests
and examinations, and then furnishes this information
back to the teacher. The computer monitors on a
day-to-day basis the progress of the youngsters through
the program. (56:1)

Through the cooperative efforts of the American Institute
for Research, the Westinghouse Learning Corporation, and 13
school districts in California, Massachusetts, New York,
Pennsylvania, and West Virginia, PLAN was initiated in September,
1967. (57:1) Each of these school districts is linked to an
IBM/360 Model 50 computer in Iowa City, Iowa. (56:3) When
the program first started, grades 1, 5, and 9 were involved.
(57:1) Later, the program expanded to include grades 2, 6, and 10,
and in a few years it expects to be operating in all grades. "Mathematics, language arts (English, reading, etc.), science and social studies are presently involved in PLAN." (57:1)

To start the child in the PLAN program, a series of placement tests is given. A child's reading ability, interest, and favorite way of learning are determined. After the results of this information are determined, the computer analyzes the information to decide what level of material the child should study.

The student, his teacher, and his parents help determine what goals they feel the child should meet. Often, the child is graded against his own goals. In this way, the child is competing for success only against himself. A picture of children at work in the PLAN program is found on the following page.

In the PLAN classroom the teacher assumes a more professional role. Her time is no longer occupied with paper work, but rather, she is free to assist the children with specific problems and help them plan specific courses of action. The teacher also has more time to help develop specific courses of study for each student.

One of the biggest assets of the PLAN program is its cost. While many of the computer-assisted programs cost as much as $400 to $1000 per pupil, PLAN costs $100 per student. (27:36) One reason that the cost is so low is that PLAN uses material that already has been prepared by other companies. Material does not have to be converted into computer language.
nor does it have to be developed; just organized. By not having the students interact with the computers, the terminals, very expensive devices, are alleviated.

The true evaluation of the program will come when a research study compares the achievements of students using computer-managed instruction with those of students using computer-assisted instruction. Then cost per project can be compared to achievement per project.
Advantages

Many advantages of the use of Computer-assisted Instruction were confirmed or discovered through the research projects (some of which were discussed in section III of this paper) that were conducted. Research showed that the "great advantage in the use of the computers lies in their ability to locate information and solve problems with tremendous speed and accuracy." (25:78) Another "...tremendous advantage of using computers lies in their ability to meet the unique needs of each school system. For this reason, it is generally undesirable to transfer a computer program from one school system to another without first making modifications." (54:40)

Advantages for Students

One of the most important advantages of a computer-assisted program is the computer's ability to give immediate feedback. As the child works through the program, he is corrected when his answer is wrong. At the end of a lesson he is given a print-out of the material he has just covered. This print-out lists the questions that have been asked and shows the pupil's responses. The importance of immediate feedback in mathematics is stated in the following:
"If a child does a math problem in regular class, he may do a whole page of problems all wrong," said one of the teachers at Brentwood in Palo Alto, California. He will reinforce his errors, actually learn his mistakes. "When he does math in CAI lab, the machine tells him as soon as he makes his first mistake and he can correct it right away, before it becomes a habit." (37:73)

CAI allows each student to work at his own rate. The bright student does not have to wait for the rest of the class to catch up with him, nor does the slow student feel helplessly lost. The computer presents material in a logical sequence; reverting to drill for those who need review, skipping material for those who are advanced in the subject area. This ability to individualize instruction allows a pupil that has been absent from class to catch up on his material without making the rest of the class wait for him or making the teacher spend a great deal of time tutoring him.

The computer is especially good for drill-and-practice activities. The activities might include such areas as: mathematics, spelling, and factual information. "Competence in performing arithmetical operations is achieved through CAI in a third to a fifth of the time required by conventional methods. (1:855)

School differences in staff, equipment, and funding may also be equalized by the use of computers in a school.

The possibility of bringing enriched programs to students in a variety of environments where such courses cannot reasonably be offered by the teaching staff, either because of lack of time or because of lack of training, is probably one of the most immediate practical aspects of computer-assisted instruction. (50:950)
The computer is able to use a wide variety of presentation modes such as audio, slides, movies, and graphics. (12:7) The computer uses these media to do more than just present facts; the computer demands a response. Because the computer does demand a response, the development of attention span and ability to follow directions are improved.

The computer is very patient. Being a machine, the computer, "...does not get tired, hot, cold, cross, or impatient, although it may occasionally blow a fuse." (39:18)

Robert Bundy, in reporting on research findings, states the following conclusions:

1. Students seem to learn at least as well with CAI as with conventional classroom instruction.
2. CAI can provide learning and retention at least equivalent to conventional techniques in the same amount of time.
3. The computer learning program can make logical decisions and adjust to individual student differences.
4. The computer can record and manipulate a wide variety of learning data about the student sequence of learning steps, response time, number of errors, etc.
5. The computer can reduce certain kinds of tedious work usually required of the student on in mathematical logic.
6. The computer program can integrate and control a wide variety of audiovisual aids for enrichment and motivation.
7. Time sharing is within the capabilities of present technology.
8. No known limits have been reported to the kinds of subject matter or conceptual level that can be programmed.
9. Students are generally interested in and like CAI. (9:7-8)

Advantages for the Teacher

The advantages that the computer offers are not only enjoyed by the pupil, but the teacher also receives advantages.
The computer does the tedious, non-professional work such as grading papers, recording grades, and preparing reports. The computer also takes over drill-and-practice exercises, thus allowing the teacher even more time to work with students on an individual basis.

The greatest asset to the teacher is probably the print-out sheets that she receives at the end of a lesson. These sheets tell her what drill each student worked on, how many problems the student answered correctly, how many time-outs the child had, and any specific area the pupil had trouble with. The teacher can use this information to help those children who need her aid. The computer provides a more complete daily record than was possible before.

Advantages for the Administration

The computer can be very advantageous for purposes other than instruction. The computer, which is especially helpful in administrative work, can keep student records up to date in a fraction of the time needed for manual recording. Registration papers, record cards, and diplomas can be prepared by the computer. Payrolls are also prepared with ease.

According to a survey on computer usage taken with this year's (1970) CAVI survey, an estimated 4,300 school districts in the United States use computers. Of these, more than 3,700 use them for administrative purposes, about 1,000 use them for classroom instruction and approximately 400 of these districts use computers for both purposes. (20:13)
Scheduling is made easier with the use of the computer.

By inputing keypunched cards of information on teachers, rooms, students, and course requests, a Burrough 360 computer can generate a master schedule for a school population of 1000 in about 4 hours, providing there are no errors in logic. A comparable schedule, manipulated by hand and containing the same time pattern variables, would take several thousand man hours. (15:136)

The computer is an aid in budgeting and inventory taking. In one school system the computer was used to determine which cafeterias were operating at a loss. Then, plans were submitted to the computer for a better means of operation. The results were that the cafeterias are now operating at a profit. (19:105)

Computers may even be used to test innovations.

In the school of the future, an innovation might be old by the time it is tried on the students. It will have been tested by a computer first.

Through simulation, the computer can aid in school management and decision-making by acting out a plan and informing the administration of the consequences. In a few minutes, the computer can go through a procedure that would normally take a full year's time and thus enable educators to try out radical innovations without suffering the potentially harmful results. In addition to exploring the feasibility of new ideas, the computer can point out needed improvements in existing activities. (18:21)

Other uses for the computer in administrative work will probably be discovered as more work is done with the computers.
Disadvantages

With all the advantages of computer-assisted instruction, one might wonder why computers are not in use en masse. There are also disadvantages associated with the use of computers. Featherstone, in his review of Gettinger's and Marks' book entitled Run, Computer, Run, quotes the authors as saying:

...Far from freeing teachers from routine, the new equipment piles on more mechanical and clerical work: testing, recording, setting things up, storing and installing tapes or programs. The aim is to "individualize" instruction, but this is seldom the result. There is a strong emphasis on planning and maintaining schedules. Often the protection of the expensive equipment takes precedence over learning. (Chewing gum is a major threat.)...The new technology is neutral to such important matters as grading and grouping patterns, which continue unchanged. The extent to which existing computer-assisted instruction responds to individuals is minimal.... Theoretically, it's possible to create all sorts of complex, branching programs that can adapt to any number of responses from students. In our present state of profound ignorance, however, it is hard for any programmer to anticipate more than a few simple alternatives. So the learner has to fit himself to the program, which is where we came in. (20:11)

Cost

Although some people may be of the same opinion as the authors of Run, Computer, Run, one of the main reasons that most schools do not have computers is the cost.
An economic assessment of computer-assisted instruction, based on over 2 years of analysis, indicates that annual costs are now about $400 per student for the drill-and-practice mode, and about $1000 per student for the tutorial mode. (8:970)

This averages out to about $2 to $5 per student per student-contact hour. (3:1586)

There are three main elements in CAI costs: central processing computer units, communications, and terminals. The first is going down and in a few years the cost of computers and large scale memory will be very favorable. It is not likely that communications and terminal costs will show a corresponding decrease. (50:7)

The following is a list of computer expenses:

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Salaries for administrative and instructional staff</td>
<td>$75,000</td>
</tr>
<tr>
<td>Salaries for paraprofessionals (30 in 16 schools)</td>
<td>$85,000</td>
</tr>
<tr>
<td>Salaries for computer operators</td>
<td>$23,000</td>
</tr>
<tr>
<td>Teacher training workshops and in-service courses</td>
<td>$15,000</td>
</tr>
<tr>
<td>Supplies for computer operation and central offices</td>
<td>$17,000</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>$19,000</td>
</tr>
<tr>
<td>Curriculum charges</td>
<td>$20,000</td>
</tr>
<tr>
<td>Hardware</td>
<td>$230,000</td>
</tr>
<tr>
<td>Miscellaneous (cable, furniture)</td>
<td>$294,000</td>
</tr>
<tr>
<td>Total</td>
<td>$615,000</td>
</tr>
</tbody>
</table>

(11:7)

These figures are for the 16 schools in New York City for one year.

One approach that might help to cut the cost of a computer system is the time-sharing approach. A computer could be set up in a central location, and terminals could be set up in various schools. At an allotted time each school could use the computer and share the expense for its use.
The production of programs is another problem in the use of the computer system. It is difficult to find teachers and technicians who are skilled in writing programs. The program writer must not only be cognizant of the subject matter and educational theories, but must also know computer language. When one considers that there is a different language for each type of computer, one realizes that it is no easy task to write a program. Each lesson that is written requires several commands that have been coded in computer language.

A typical lesson in the reading program, which takes the average student about 30 minutes to complete, requires in excess of 2,000 coursewriter commands for its execution. (4:23)

It takes time to prepare a program like the one mentioned above. Besides the detailed list of commands that must be programmed, all messages that the student might hear must be recorded. If the program is going to contain visual aids, these must be recorded on filmstrips. "Estimates are that it takes 40 hours of human labor to develop one hour's worth of instructional material for the computer." (18:9) This means that "conservatively, it does seem to take a minimum of 10 to 20 man-years to prepare a 1-year course." (48:102) After all this work and time, most programs are not interchangeable. The programs must be revamped or completely reprogrammed to run on different computers.

The amount of time that it takes to develop a program is further dependent on the type of program that is written.
According to Patrick Suppes of Stanford University, it will be some time before an adequate amount of material for the tutorial system can be prepared. If the drill-and-practice system is used, it will take less time to prepare the programs. Mr. Suppes predicts:

...drill-and-practice materials will be the ones adopted by our school system in the initial years and will find widespread adoption in other schools. However, over the years an increasing body of tutorial materials will be prepared, and as the economics of tutorial instruction become more feasible, a more extensive use of them may be anticipated. (48:107)
The Teacher's Role

The use of the computers in the elementary classroom will change the role of the teachers in those classrooms.

The role of the teacher will be drastically changed. The teacher of tomorrow has been described as a classroom manager, a physician instead of a pill dispenser. His primary job will no longer be that of presenting information. He will be free of many of the monotonous tasks that now consume much of his school day, such as drilling students, correcting tests, or keeping track of paper work.

Instead, the teacher can devote more to diagnosing individual learning problems, leading small group discussion, developing them with communication skills and social relations, developing and coordinating the use of curriculum materials, and in general, serving as an inspirational model.

The teacher, then, will be concentrating his time on doing the things a computer can not do. His responsibilities will be upgraded, demanding more skills, not less effort. Said U. S. Commissioner of Education Harold Howe II: "A computer cannot develop a student's ability to associate effectively with other people. It cannot train a pupil to originate ideas, to present them and defend them against criticism, or to talk confidently before a group. It cannot foster creativity, stimulate thought, encourage experimentation, (or) teach students to analyze." (18:9)

Duncan N. Hansen and William L. Harvey, both of Florida State University, have proposed the following changes in the teacher's role when using CAL:
1. The teachers will perform much less of the informational presentation functions presently found in our classrooms. Undoubtedly, the teacher will become much more involved in the managerial and strategy functions found in the sequencing and evaluation of the instructional process.

2. Teachers will play less of the corrective role in terms of their questioning and evaluative behaviors. This undoubtedly will offer a significant step forward in teacher-student relationships in that much of the negative verbal behavior observed in classrooms will now be shifted to a more individualized and private interaction within CAI.

3. Teachers will become much more concerned with the host of individual characteristics important in designing an instructional strategy; thus the array of instructional resources and the decision making found in employing these resources will become more complex and also more frequent in terms of teacher behaviors.

4. The teacher will have a greater involvement in guiding individual students rather than maintaining classroom discipline. With the computer relieving the teacher of the informational presentation tasks, she will be able to devote the time usually expended in group communication to individual counseling and advising.

5. Teachers will have to perform a wider range of discussion techniques involving a richer opportunity to affect the social and emotional behavior of students. Teachers will have to have greater skill and understanding of human behavior viewed in the broadest terms. This requirement may in part be aided by the CAI system's information retrieval capability which may monitor the patterns and rates of student development.

6. It is clear that the teachers will have a greater array of differentiated professional(s) joining them in the team effort to provide optimal instruction. Thus some teachers may become experts in the guidance process, while others may become more competent in the application of technological procedures and functions for the fullest employment of computer technology.

7. Teachers may take on many more of the diagnostic assessment and prescriptive functions presently assigned the school psychologist. Teachers may, in fact, utilize more group interactive procedures in an attempt to develop latent social and creative talents within their students.

(261:5-6)

The change in the teacher's role will also necessitate a change in teacher training. A new teacher will have to know more about the computer and its operation.
This requirement for new teaching competencies ...would necessitate the training of teachers in the knowledge and behaviors necessary to operate many of the functions of the computer, i.e., teachers would be required to understand the operational procedures of the computing system, how to sign on and off, plus the multitude of specific directions which absorb so much of our current activity in the CAI world. (26:3)

The teacher would also have to be instructed in the methods of writing his own programs. Patrick Suppes:

Teachers will be no better prepared to write curriculum materials, once computer-assisted instruction is the mode, than they now are to write them for regular textbook publication. In fact, I would predict that they will be even less able to construct appropriate curriculum materials once individualization of materials becomes the major theme of computer-assisted instruction. (48:107)

Instruction in leadership for group discussion will also be necessary. Teachers will need more skills in the area of group-interaction. This will require a change in the structure of the methods classroom. Lecture techniques will no longer be sufficient to prepare the classroom teacher for her role.
Future

What will the future of computers in the elementary school be? Will computers go the route that programmed instruction and educational television have gone: seen as the panacea in education at first, later seen as just an additional aid? Some, like Oettinger and Marks, feel that there is little use for the computers in the school. Others, like Wesley W. Walton of the Education Testing Service, say:

I am of the school that looks upon the computer as the most significant development since the Gutenberg press and the library. I believe it will do more to change our way of life than the Industrial Revolution did. (29:10)

In assessing the future of computers one must take the development of the current programs into consideration. Patrick Suppes says that there are three stages of development for computer-assisted instruction.

For the most part we are still in the first (stage), but we are moving into the second. In the first stage we have the beginning of CAI in a serious operational sense--students being processed daily--organized around major research centers at

...universities.

In the second stage, school systems operate demonstration efforts for small groups, without attempting to teach the total school population. We are just getting into this stage now, and a large number of HEW Title III proposals are being developed for this purpose....

In the third stage, school systems will attempt to make CAI an operational part of their
regular school operation and have it reach every student of a given age level and in a given curriculum. It will be a couple of years before we reach this saturation stage in any curriculum area for any significant number of school systems. (12:6)

In some schools the third stage development has been reached. In these situations the effectiveness of the program must be evaluated.

Initial use of these drill-and-practice materials on large-scale, operational CAI systems indicates that students do learn significantly more in daily computerized drill sessions continuously adjusted to their individual learning rates and capacities. They are better motivated to learn, they learn faster than by traditional drill methods, and they retain what they learn significantly longer. (27:63)

The computer is also liked by the students. In New York City, where the nation's largest CAI system in the public schools is located, administrators found that the computer was serving students eleven hours a day on four days of the week. (11:84) Students may like the computer because it helps to individualize instruction.

The ever-increasing dependency of education upon the computer seems inevitable because it helps meet the needs of students for greater individualization of instruction and greater relevance of subject matter, and the growing expectation of society for a higher degree of accountability and efficiency in the schools.

Computer use does not mean dehumanizing. In fact, data from studies thus far indicate that one of the strengths of the computer in instruction is that it greatly humanizes the students' educational experience. The major responsibility of the educational community in this matter is vigorous and continual vigilance. (54:40)

Another factor that seems to point to the inevitability of computers in education is the interest that many companies display for computers in education.
There has been a rash of mergers of "hardware" and "software" (program developers and educational publishers) companies—over 120 since 1964. For example, Raytheon bought D.C. Heath; Xerox acquired American Education Publications; RCA took over Random House; and Litton purchased American Book Company. (45:135)

Such companies as Philco Ford, IBM, Westinghouse, General Electric, Honeywell, derg-Warren, AT and T, and Eastman Kodak "are only a few of the firms providing printed, audio, visual, and graphic CAI programs in the nation's schools. (29:26)

There are other reasons why Patrick Suppes feels that computers have a bright future in education.

There are at least four major reasons for believing that computers will come to be of great importance as instructional devices in schools. The first and most important is that the great speed of computers makes it possible to offer individualized instruction to a large number of students simultaneously. This individualization has at least two major aspects: a) the student's own responses can be corrected and evaluated immediately, and b) the type, the level of difficulty, and even the character of the curriculum material being presented to the students can be varied according to the student's level of ability and achievement. The second main reason for holding that computers will assume an important place in instruction is their capacity to relieve teachers of routine work.... The third important aspect of computer-assisted instruction is the ability of the computer system to provide administrators and supervisors with detailed information about the progress and achievement of students. Finally, the fourth major advantage is to provide data, and data analysis, for those concerned with research in the learning of children and the specific development of curriculum to maximize that learning. (44:99)
Summaries and Conclusions

The computer was placed on the commercial market in 1950 and was first used for educational purposes in the early 1960's. Since then many research programs have been conducted across the nation. The results of these programs are still in the early stages of analysis.

Of the five types of computer systems, the drill-and-practice system has met with the most success. It is not as expensive to operate as the other systems, nor are its programs as time-consuming to prepare. Because of these factors more projects have been conducted using the drill-and-practice system.

The future of the computer as an instructional tool will depend upon how teachers, administrators, pupils, and parents view the computer. These people must feel that the advantages of immediate feedback, individualized instruction, and teacher print-out information outweigh the disadvantages of cost and program supply. Whether the computer will gain full-scale acceptance remains to be seen, but the possibility is an important one for teachers to consider since their role will be drastically changed if computers are in widespread use.
appendix

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Sources of Free Computer Information

You and the Computer
Honeywell, Electronic Data Processing Div., 151 Needham St., Newton Highlands, Mass. 02161.
Franklin: High School, Computer Application Profile
Honeywell in Education
Data Processing Technology in Education
(A Case Study)
International Business Machines Corp., Armonk, N.Y. 10504.
More about Computers
Electronic Data Processing for the Layman series
Bk. 1. What Is Data Processing?
Bk. 2. What Is Binary Arithmetic?
Bk. 3. What Is a Computer?
315/RMC: The Compatible Family of Computers
Century Series
RCA Instructional Systems, 530 University Ave., Palo Alto, Calif. 94304.
You're an Educator: By Definition, then, You've Got Problems
Sperry Rand Corp., UNIVAC Div., Att'n Community Relations Dept., P.O. Box 8100, Philadelphia, Pa. 19101.
How the Computer Gets the Answer (Life reprint)
Input for Modern Management, quarterly
Mighty New Servant to the Mind of Man
This Business of Computers—a Photographic Essay
Teletype Corp., Dept. 1155, 555 Touhy Ave., Skokie, Ill. 60076.
How to Get Answers to Your Questions about Teletype Equipment
U.S. Atomic Energy Commission, P.O. Box 62, Oak Ridge, Tenn. 37830.
Computers
Automatic Digital Computers

(55:17)
Bibliography


(1965).

16. Dick, Walter; Latta, Raymond; and Rivers, Leroy.
"Sources of Information on Computer-Assisted Instruction."

Palo Alto, California, (Westinghouse Learning Corporation) 
(n.d.)

in Education. Washington, D.C.: National School 
Public Relations Association, 1968.

19. Edwards, John P. "A City and School System Share a 

20. Featherstone, Joseph. "Classroom Gadgetry," New Republic, 

Educational Heart Transplant, Computer-assisted 
Instruction: A Brief Review of Research," Contemporary 

22. Gilman, David Alan, and Hernandez, Ivan. "The Retention of 
Concepts as a Result of Several Feedback Modes in 
(Address presented at the Department of Audiovisual Instruction/ 
NEA Meeting.)


25. Gottesman, Alexander M. "Education in the Seventies," 
Peabody Journal of Education, 45:76-81 (September, 
1969).

26. Hansen, Duncan N., and Harvey, William L. "Impact of 
CAT on Classroom Teacher," Tech Memo No. 10, 
October 15, 1969. (Document of the Personnel and 
Training Research Programs Psychological Science 
Division, Office to Naval Research, Washington, D.C.).


56. Westinghouse Learning Corporation. PLAN. Palo Alto, California, (n.d.).
