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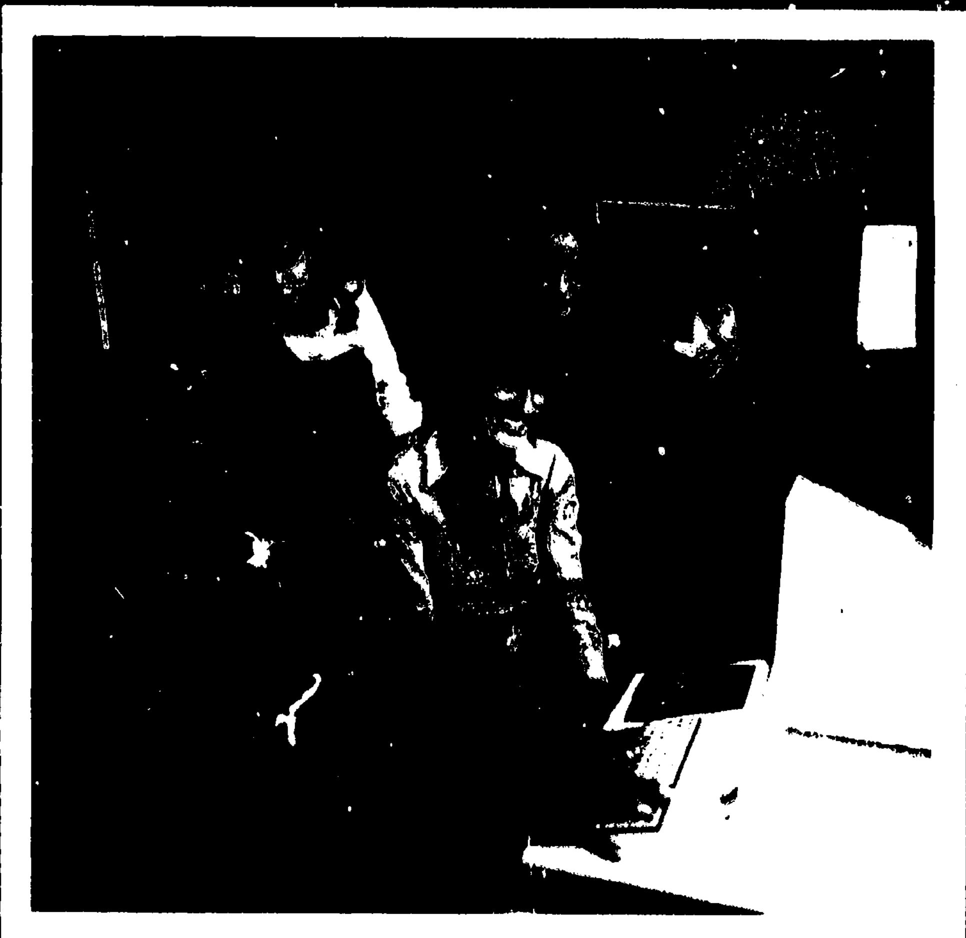
ABSTRACT

The findings of research on computers and teaching are reviewed in this monograph, both to provide useful guidelines for teachers, and to serve as a reference point for further research. Research results are organized around the following topics: (1) computer availability and use; (2) classroom applications--computer assisted instruction, computer managed instruction, testing and recordkeeping, and instructional games; (3) curricular applic ons--language arts, mathematics, science, and social studies; (4) exceptional children; (5) attitude and motivation; (6) large computer systems--PLATO and TICCIT; and (7) future issues and concerns--the videodisc, software (quality control and software protection), quality of research, relationship with industry, networking, teacher training, and effect on formal education. A concluding statement briefly discusses some advantages of and problems with computer use, and an 85-item bibliography is provided. (LMM)

What Research Says to the Teacher

The Computer and Education

by Marvin N. Tolman and Ruel A. Allred



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The opinions expressed in this publication should not be construed as representing the policy or position of the National Education Association. Materials published as part of the What Research Says to the Teacher series are intended to be discussion documents for teachers who are concerned with specialized interests of the profession.

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CONTENTS

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INTRODUCTION

The computer is influencing many aspects of learning in both the school and the home. An understanding of its role and potential is therefore of the utmost importance to educators as they look to the future. The early popularity of the microcomputer, enhanced by its ability to excite users with novel and interesting games, is now giving way to more practical and educational applications. Technological advances, accompanied by the production of high-quality software, continue to increase its potential as an educational tool.

The computer lends itself well to the study of many subjects. It can present and store information, motivate and reward learners, diagnose and prescribe, provide drill and practice, and individualize instruction. These are only a few of its useful features with potential to enhance learning.

Of particular interest to teachers are not only the effects the computer will have on future learning, but also the influence it will have on the interpretation and application of past research findings. Some instructional approaches that have been tried, tested, and proved valid without this technology may not be feasible with its use. Other methods that have not been of value by themselves may be effective when used with the computer. Still others will continue to work well with or without it.

At this early point, one might expect to find a limited amount of computer research related to teaching. However, studies in the literature are starting to give an indication of the computer's instructional value. The major purpose of this monograph is to review these findings to provide useful guidelines for teachers. Another purpose is to serve as a meaningful benchmark or reference point for future research in an area that is in the process of exploding. To accomplish these purposes, research findings are organized according to the following topics: (1) availability and use, (2) classroom applications, (3) major curricular applications, (4) exceptional children, (5) attitude and motivation, (6) contributions of large computer systems, and (7) future issues and concerns.

AVAILABILITY AND USE

During the past few years, the availability and use of the computer in education have undergone rapid changes that will have a major impact on students, teachers, and the educational process. Knowledge of the educational status of the computer should therefore help teachers plan for the future. The information that follows comes from investigations into its past and current accessibility and use.

Past Availability and Use

According to surveys conducted in 1970 by the American Institutes for Research (AIR), 34 percent of this nation's public secondary schools were using computers to aid their administrative and/or instructional programs (11).* A

*Numbers in parentheses appearing in the text refer to the Bibliography beginning on page 28.

followup survey, Project CASE (Computing Activities in Secondary Education), showed that during the next five years secondary schools experienced a "quiet revolution that has seen the modernization of school administration and the enrichment of the learning process" (11, p. 9). This survey showed a 24 percent increase, to 58 percent, in the level of secondary computer use. The 1975 data revealed that 31.5 percent of responding schools were using the computer for administrative purposes only, 4.9 percent for instruction only, 21.8 percent for both administrative and instructional application.

In 1976 Bukoski and Korotkin (11) predicted that by 1984 every secondary school in the country would have access to some type of computer system for administrative or instructional application. The advent of the microcomputer on the heels of this prediction virtually assured its fulfillment. Many computer-enthusiast educators now look for the time when each desk will have a computer.

Perhaps typical of what might be found in America's schools in transition are the results of a 1982 survey conducted at Palatine High School near Chicago to determine the rate of microcomputer implementation in the curriculum (32). Twenty-two of the seventy-four responding teachers reported they used microcomputers. Frequency of use ranged from "very often" (three) to "often" (five) to "seldom" (fourteen). The most common reasons given for not using microcomputers were "lack of training" and "lack of time." The total number of microcomputers reported in the school was eight—four assigned to the mathematics department, two to the business department, and one each to the science and industrial education departments. Because teachers in these departments received priority in daily in-service training, other teachers felt they were "on the outside looking in."

In 1982 about 45 million students enrolled in 2 million classrooms of 100,000 schools in the United States (4, p. 10). Approximately one out of every three of these schools had at least one microcomputer or terminal connected to a larger computer. The total number of such microcomputers and terminals was estimated to be between 200,000 and 300,000. Becker suggested that the number of schools with microcomputers had "approximately doubled annually for a number of years" (4). At this rate by 1986 there will be an average of ten computers per school or one for every two classrooms.

In the spring of 1982 the National Education Association (NEA) conducted a survey to determine the level of computer use in schools throughout the country (63, pp. 5-32). This survey involved a sample of 1,700 teachers, randomly selected from the association's national membership file. Of the teachers surveyed, 65.2 percent worked in school systems that used computers for administrative purposes, 28.8 percent reported the presence of a computer in their schools, and 10.9 percent reported the presence of a computer in a classroom. The survey found that computers were used at all levels—elementary through senior high school—with the greatest percentage of use in mathematics—70.7 percent—followed by reading—34.7 percent—and computer literacy—32 percent.

According to the NEA survey, people outside the profession blame teachers for the low incidence of current instructional computing, claiming that teachers are not interested in the computer because they fear the impact of the technology on their careers. Contrary to this notion, the survey found teachers expressing a desire to use the computer and viewing it as a positive influence on instructional effectiveness, job satisfaction, and professional challenge.

Current Availability and Primary Uses of Microcomputers

Another national survey—*School Uses of Microcomputers*—was conducted by the Center for Social Organization of Schools (CSOS) at Johns Hopkins University. This study was based on a sample of 2,209 representative public, private, and parochial elementary and secondary schools in the United States. The information that follows comes from its two reports (15, 16).

Although secondary schools remain the largest precollege users of microcomputers and their "overwhelming emphasis" is to teach students "about" computers and how to program them, the majority of software marketed for schools is geared to the elementary level and "built around the premise that microcomputers can be cost-effective means of increasing the rate at which students learn rules of arithmetic computation and proper English language usage" (15).

As of January 1983, 53 percent of all schools in the United States had obtained at least one microcomputer for instructing students (up from 38 percent in June 1981). This availability ranged from 42 percent of the nation's elementary schools to 85 percent of the high schools. Even the smallest secondary school with under 200 students is more likely to have at least one microcomputer than is the largest elementary school with over 700 students In January 1983, two-fifths of all secondary schools had five or more microcomputers. Ten percent of those schools were using "network" systems of some kind, as were 1 percent of microcomputer-owning elementary schools (15).

At both the elementary and secondary levels, the most frequent use of microcomputers was to introduce students to computers, an application found in 85 percent of computer-owning secondary schools and 64 percent of computer-owning elementary schools. At the secondary level, programming instruction ranked second in frequency of use at 76 percent of user schools, with drill-and-practice third at 31 percent. At the elementary level, drill-and-practice was in second place at 59 percent and programming instruction in third place at 47 percent. Twenty-four percent of the elementary schools and 19 percent of the secondary schools used microcomputers for recreational games. Administrative use was at 14 percent for secondary schools and 10 percent for elementary schools. Word-processing application by elementary and secondary schools was at 3 percent and 7 percent respectively. (See Table 1.) Of the schools teaching programming instruction, 98 percent used BASIC; 5 percent used FORTRAN, LOGO, and PASCAL, with some schools using more than one of these computer languages (16).

Table 1
Major Uses of Microcomputers
in Microcomputer-Owning Schools

Schools	Computer Literacy	Programming Instruction	Drill and Practice	Recreational Games	Administrative Applications	Word Processing
Elementary	64%	47%	59%	24%	10%	3%
Secondary	85%	76%	31%	19%	14%	7%

Although microcomputers are present in a majority of U.S. schools it does not follow that most students are receiving exposure to them or that the computers are being used to capacity. In about half of the schools with micros, only one or two teachers are regular users; in the other half more than two teachers either use packaged programs or teach computer programming to students. Rarely do more than two teachers in a school teach programming to students at either the elementary or the secondary level (16).

Elementary schools are more likely than secondary schools to expose students to the microcomputer. In about one-third of the micro-owning elementary schools, more than 40 percent of the students have some contact with a microcomputer. This is true for only one out of every eight micro-owning secondary schools. About 13 percent of the secondary students and about 16 percent of the elementary students use the technology during any given week. "Typical" weekly use is 11 hours at the elementary level and 13 hours at the secondary level.

About one-fourth of all student time on microcomputers in precollege educational institutions occurs at the elementary level; the remaining three-fourths occurs at the secondary level. At the elementary level, one-third of the student users have access for 15 minutes or less per week, and only one in 50 has more than one hour per week. Secondary student users have about twice as much access time as elementary students—nearly 40 percent have access for more than one hour per week during their weeks as users, and about the same proportion has 30 minutes or less. As elementary schools acquire more micros, they tend to give access to more students, whereas secondary schools are more likely to provide longer access to the same number of students (16).

Research verifies that the use of computers in education is still in its infancy. Students receiving computer experience are in the minority and even they get only a few minutes each week. The problem of an insufficient number of computers in the school will persist for some time to come. One possible solution is to have students share computer time. At least one study (31) indicates that students can learn in pairs at the computer about as effectively as they can learn singly.

To summarize, studies of computer availability and use show dramatic increases during recent years. Approximately 85 percent of the nation's secondary schools were using microcomputers for instructional purposes in 1982—up from the 27 percent instructional use of 1975 and substantially surpassing the 34 percent combined instructional and administrative use of 1970. Forty-two percent of the nation's elementary schools were using the microcomputer for instructional purposes in 1982. In both elementary and secondary schools the most frequent use was to introduce students to computers. Other uses were programming, drill and practice, recreational games, and word processing. For several years the number of microcomputers in all schools has doubled annually. By 1986 it is expected that each school will have an average of ten, or one for every two classrooms.

CLASSROOM APPLICATIONS

Computers have been successfully applied to instruction in a number of ways, ranging from routine services such as recordkeeping and checking tests to assisting students in practicing skills previously learned and learning new material. Much effort has been directed toward individualization. Although this section describes some classroom computer applications, the primary purpose is to report the results of these efforts shown by research. Teachers who wish to identify additional classroom applications and obtain ideas for implementing them will find such sources as Moursund (60) and Kepner (44) helpful.

The following pages discuss research related to (1) computer-assisted instruction, (2) computer-managed instruction, (3) testing and recordkeeping, and (4) instructional games.

Computer-Assisted Instruction

In computer-assisted instruction (CAI) students interact with computers, with information and/or stimulus material presented on monitors. Usually the student receives feedback from the computer, which maintains some degree of control over the sequencing of material (5). CAI has been the object of much attention; research has been conducted on student attitudes, self-concept, sex differences, education of the handicapped, and many curricular areas. Most studies reveal positive effects on the factors considered and conclude that a traditional program supplemented with CAI is frequently more effective than programs that use traditional methods alone (12).

Proponents of CAI have high hopes for the computer as a tool to assist in identifying and meeting individual needs. On the other hand, CAI has also been the object of criticism, especially in the premicrocomputer era when hardware costs were high and educational software was scarce. As a proponent of computer use to relieve the teacher of burdensome paperwork, Crouse charged that "instead of using the computer as an assistant to the professional staff, educators have been trying to make it a member of the profession in the guise of computer-assisted instruction" (19, p. 16).

Many investigations have targeted the effectiveness of the computer as an aid to learning. Burns and Bozeman's study (12) provides strong evidence that a curriculum supplemented by CAI leads, at least in some subject areas, to improved student achievement. Saracho (70) found that students who used CAI made greater achievement gains than did nonusers.

Studying the effectiveness of the lecture and CAI with college students learning a computer programming language, Tsai and Pohl (77) compared three teaching/learning environments: lecture (LI), computer-aided instruction (CAI), and lecture supplemented with computer-aided instruction (LCAI). These investigators found no significant differences in achievement for students in any group when achievement was measured by either homework or term project scores. However, when student achievement was measured by quiz or final exam scores, significant differences resulted, indicating LCAI to be the most effective and LI to be the least effective of the three methods of instruction.

After reviewing much CAI research and interviewing many researchers, Gleason reached the following conclusions:

1. CAI can assist learners in attaining specified instructional objectives.
2. A substantial saving (20 to 40 percent) in time can be achieved for learning as compared with "conventional" instruction.
3. Retention following CAI compares well with retention following conventional instructior

4. Students react positively to well-designed CAI programs; they reject poor programs (29, p. 16).

The level of success reported with CAI is impressive, considering the newness of the technology in the classroom.

Computer-Managed Instruction

The objective of computer-managed instruction (CMI) is to collect and process information to enable the instructional staff to provide the best learning environment for each student. One basic difference between CAI and CMI is the recipient of the computer information. In CAI, it is intended for the student; in CMI it assists the teacher in the management of learning.

Cost-effectiveness is a consideration in the use of this computer application. In at least some instances of CMI implementation, the equipment and materials prove to be cost-efficient. Studies conducted in a vocational setting indicate that successful development and implementation of a viable CMI system for individualizing instruction is feasible (25). Van Hees (78) reported that a computer-managed learning system in the Netherlands resulted in improved student services, the ability to handle larger groups of students by fewer staff members, and improved course evaluation. Another study compared the achievement of fifth-graders using CMI with that of non-CMI groups and found no significant difference (68). However, CMI "was effective in relieving teachers of clerical burdens and the quality of instruction in CMI schools was found to be quite satisfactory."

One of the most ambitious CMI projects is that operated by the U.S. Navy to train military personnel. The objective of the system is to increase training efficiency and reduce the cost and number of training personnel. Scanland (71) reported that through redesigned programs and individualized instruction, made possible by CMI, the average time required to master content was shortened by 42 percent, while the student-to-staff ratio was reduced 23 percent. At the same time, student performance was improved and attrition rate declined. Recent information indicates that CMI currently plays a significant role in the training of naval and other military personnel.

Testing and Recordkeeping

Using the computer to check and analyze objective tests is a common practice that has proved an effective means of appraising student performance and providing item analysis data (74,3). Hoffman and Lundberg (39) reported a study of this computer use with pharmacy students at the University of California. In this case students in a large auditorium pressed buttons of a computer-monitored response system to indicate their responses to test items presented visually on 35mm. slides projected on a large screen.

This system was compared, under carefully controlled conditions, with similar tests administered to the same students in a conventional classroom setting. The results showed no significant performance differences between the conventional administrative mode and the computer-monitored mode for true-false and multiple-choice items. In matching items, students did better with the conventional mode, a result attributed to the freedom to go back and change previous answers. At the end of the entire test session, the computer provided a printout of test item analysis as well as each student's raw score, percentage score, and class rank. The researchers (39) felt that instant feedback provided the teacher in a video display at the time of response and in hard copy immediately after the session made the system an appealing method of test administration.

For another study, Crouse (19) designed a "computerized gradebook" to use with the microcomputer. This system checked tests and provided test scores, final reports, and standard gradebook information. It gave students their cumulative average after each test and provided teachers with an item analysis as well as student test scores. Studies indicated that the system furnished valuable feedback to both teacher and student and resulted in substantial savings in teacher time.

The Madison, Wisconsin, Public Schools used a computerized reporting system as an alternative way to construct evaluation reports (64). The system included a pool of comments from which to select appropriate items for individual student progress reports, thus reducing the tedious task of writing comments. In addition to the individual student progress reports, the computer used the same information to produce a quarterly class report for each teacher and an annual "Pupil Progress Summary" for the permanent records. This minimized the need for interim quarterly reports in student folders and reduced clerical costs. Data gathered indicated positive attitudes of administrators, teachers, and students toward this system, and "overwhelming support" from parents.

Instructional Games

Efforts to apply a "spoonful of sugar" to the "medicine" of learning have led to the design of many learning experiences in game formats. Computer games have been created to teach language, mathematics logic, physics, chemistry, biology, economics, business, medicine, geology, and other topics. Educators have received these efforts with varying degrees of enthusiasm. While critics question whether mixing learning with games enhances the learning experience or spoils the game, enthusiasts are using the games. Given the choice, large numbers of students opt for the games and their teachers find that these lessons are "better learned than those provided by the traditional textbook" (44 p. 48). Exploration of this area has only begun. An understanding is needed of the reasons for the human fascination with computerized games for hours at a time.

Students 8 to 11 years of age participated in a study of the effect of certain elements on computerized tutorial/games (82). The researcher found that students who had an opportunity to continue their participation in a game by responding correctly achieved significantly more than those who did not have the game opportunity. This was true even though the game-playing students did fewer exercises. The researcher concluded that games can have a positive pedagogical value for mathematics instruction and they can significantly improve learning during a computerized drill-and-practice lesson.

In a study of second graders, Kraus (49) developed and tested a computer-generated game called "Fish Chase" to present drill-and-practice exercises on addition facts. He concluded that a computer game can effectively increase proficiency with basic facts. Allen and Ross (1) found that the ability of junior high school students and their teachers to select ideas relevant to solving particular problems improved significantly through the use of instructional games.

Research findings relating to computer-assisted instruction, computer-managed instruction, and its uses in testing, recordkeeping, and instructional games, have been encouraging. CAI has been used in most educational areas including curriculum, attitudes, and education of the handicapped. In these and other settings it has contributed to the improvement of student achievement and learning rate. CMI has also shown promise for future use when used to assist teachers in the management of learning. In some instances it has been found to be cost efficient and capable of handling large groups of students.

Studies of computer use in objective-type tests, recordkeeping, and instructional games have yielded positive results. Such use has proved accurate and efficient; it also has the capacity to free the school's professional staff from tedious jobs that occupy valuable time. Instructional games have been found to improve learning significantly, particularly in drill-and-practice exercises and problem-solving activities.

CURRICULAR APPLICATIONS

Some educators feel the computer has been "heavily involved in the physics and chemistry classrooms and laboratories of the university but virtually held captive by the math department of the secondary school" (44, p. 94). With the availability of relatively inexpensive microcomputer systems, precollege computer applications are rapidly expanding. The findings cited in the following pages are examples of recent research conducted in language arts, mathematics, science, and social studies. Much is also being done to use the computer to enhance the study of other curricular areas such as art, music, theater (44, chap. 9), and foreign languages (22).

Language Arts

Many educators feel the computer belongs not only in mathematics and science laboratories, but in the language lab as well. There it provides individualized language arts and reading drill for students, makes grading and recordkeeping less tedious for teachers, and when used with word processing software, increases student interest and learning efficiency in writing skills (44, chap. 7).

In a Florida study, Fey (23) found that computer-prepared individualized reading prescriptions were faster, less costly, and more accurate than those prepared by classroom teachers or reading teachers. Studying the effect of CAI on reading achievement gains, Lysiak and others (51) found the CAI and control programs to be equally effective.

Weaver and others used CAI at the high school level to increase the skill of poor readers to locate multiletter units within words (81). In this study students were required to detect the presence of a particular unit within words shown in rapid succession. Substantial improvements were evident and maintenance tests indicated lasting results.

In a study of the interactions among component processes of reading, Fredericksen and others (27) sought to determine the effectiveness of a particular hierarchical training model in developing reading skills. This investigation used three microcomputer training systems designed in a game format. Each system targeted a skill causing difficulty to poor-reading high school students: (1) perception of multiletter units appearing within words, (2) efficient phonological decoding of orthographic information in words, and (3) use of context frames in accessing and integrating meanings of words read in context. In all cases students reached performance levels in the trained skills that "equaled or exceeded those of high-ability readers." Acquired skills were also shown to transfer to other related reading functions. Students who completed the entire training sequence also improved in reading speed, with no decline in comprehension.

Computer research projects in spelling instruction were among the first in the curricular areas. Already they include comparisons of immediate and spaced repetition, massed and distributed practice, ways to divide words for spelling instruction, sequencing, diagnosis and prescription, remediation, and individualized instruction.

Knutson (47) found that immediate repetition and spaced repetition produced substantial learning for students using computers. He also found additional practice on words to be more effective than no repetition, and spaced-repetition consistently favored over the other two methods. Fishman and others (24) reported that massed repetitions proved effective on short-term performance, but more learning occurred in the long run when repetitions of an item were well distributed.

An investigation of learning rates that used the computer to display correct spelling in several ways—by letters, chunks, or whole words—found that words displayed by chunks were learned more rapidly than were whole words (6). But words displayed by letters were learned more rapidly than either of the other two methods. However, delayed recall tests two and six weeks later showed no differences in word retention.

The computer is well suited to studies of forced sequence. Investigating the performances of poor-spelling third graders, Robertson (67) found it a useful remedial spelling technique to compel students to observe the details of a sequence. As a result, children made substantial growth in both letter and numerical forced sequence over a short period of time.

Hasselbring and Crossland (35) designed a Computerized Diagnostic Spelling Test (CDST) to imitate, as closely as possible, the administration and scoring procedures of a written diagnostic spelling test. These researchers concluded that the early use of CDST with learning-handicapped students shows promise. The test does not require a teacher to administer and score it and the system can be operated independently by learning-handicapped children as young as nine years of age. Data obtained from this microcomputer-based method reveal it to be "an efficient and cost-effective way to diagnose and remediate spelling problems."

In another effort to remedy spelling difficulties, Hasselbring (34) developed an individualized microcomputer program. He reported that students who used the Computerized Spelling Remediation Program in conjunction with daily spelling activities showed "tremendous gains on their weekly spelling performance."

The computer's potential for individualizing spelling instruction is evident, causing even researchers who found no significant differences in treatments they were studying to conclude that such individualization is feasible (21). Future research can be expected in both ways and means to use the computer in this area.

The computer is attracting attention as a tool for the teaching and learning of writing skills, both to provide feedback as a "responsive listener" (79) and to encourage the flow of ideas by easing the editing process (73). Bradley (8), who supports this interest in word processing, suggested that the microcomputer can stimulate creativity in composition even at the elementary level. Woodruff and others (84) reported two studies that explored the feasibility of using computer-assisted composition to help school-age children handle high-level aspects of the composing process. And Teulings and Thomassen (76) suggested that the computer can provide information for investigating motor control in the self-paced movements of handwriting.

Mathematics

Computing equipment was accepted in the mathematics curriculum rather early. History makes it evident that one stimulus for computer development was the need for more efficient methods of computation. Even though the computer is capable of many nonmathematical functions, manipulation of numbers is still one of its most popular uses. The highly structured nature of mathematics lends itself to relatively clear-cut research techniques and the use of the computer as an instructional tool. Hence the continuous flow of research in this area.

Burns and Bozeman (12) applied "meta-analysis" to studies of CAI in mathematics. They limited their analysis to studies that supplemented, rather than replaced, traditional classroom instruction at elementary and/or secondary school levels, and studies that compared treatment and control groups. From five primary findings they drew the following conclusions and implications:

> While no final answers related to CAI effectiveness or guarantors of success can be presented, the analysis and synthesis of many studies do point to a significant enhancement of learning in instructional environments supplemented by CAI, at least in one curricular area—mathematics. This conclusion must, however, be accompanied by a caveat—that the effectiveness of CAI or any instructional support system will be influenced by a host of variables, some uncontrollable. Failure to consider the mitigating effects of such variables will lead to a wide variance in levels of success (12, p. 37).

Success comes not only in acquiring information, but also in the amount of time required for learning. Cranford (18) compared two methods of instruction: teacher instruction only and teacher instruction supplemented by a daily 10-minute computer drill-and-practice program. Although the computer treatment had little effect on students' understanding of basic mathematics concepts, both boys and girls in the CAI group achieved at a faster rate in mathematics computation and applications than did those in the control group.

Some researchers have noted a positive effect on math skills as students learn and practice computer programming techniques. For example, Hatfield (36) compared the effects of programming a computer on two groups of seventh graders in a math course. Students in the experimental group were trained in BASIC programming and debugging skills and wrote computer programs involving the same math content taught in the noncomputer treatment. In the second year, two of six posttreatment tests showed significant differences between the two groups; both tests favored the computer treatment group over the control group. In another study, Milner (57) found that teaching computer programming had a positive effect on cognitive skills of fifth graders. He also found that the kind of learner-control experienced in computer programming can facilitate acquisition of problem-solving behaviors.

In Rockville, Maryland, nine elementary schools used Operation Whole Numbers (OWN), a computer-assisted instructional approach to the four arithmetic operations (59). Test results showed that students in each grade (3 to 6) who used the OWN program made significantly greater improvements than did those who used a traditional approach.

Another study compared three methods of introductory multiplication instruction for elementary school children: total computer instruction, partial computer instruction, and noncomputer instruction (52). No significant difference was found between the partial computer treatment group and the noncomputer group. However, significant differences were found favoring the total computer treatment group over the noncomputer group. Significant differences also favored the combined computer groups over the noncomputer group.

The Computer-Assisted Remediation and Evaluation (CARE) project, covering a two-year period that concluded in the spring of 1980, was reported to be the most extensive CAI development effort ever undertaken for the secondary schools of Ontario, Canada (28). One of its purposes was to create and evaluate CAI sequences for mathematics in grades 7 to 10. Teams of teacher representatives and research officers created six computer math courses, basically tutorial in nature and covering about 30 percent of the Ministry's Intermediate Mathematics Guidelines. The courses contained lessons, tests, and a branching strategy that advances students from one module to another in response to individual levels of performance.

Pretests indicated no significant differences between control and experimental groups of approximately 1,000 students each. Posttest results revealed that CARE students improved significantly from pretest to posttest, and improved significantly more than did the control group. Teachers indicated that using CARE as a teaching aid increased their workload but also increased their teaching effectiveness.

In its policy statement "Agenda for Action," the National Council of Teachers of Mathematics identified eight points for emphasis in mathematics education for the 1980's. One of these points states that mathematics should "take full advantage of the power of calculators and computers at all grade levels" (62). As the research cited here indicates, this effort is well on its way, but it still has a long way to go.

Science

Computer application in the secondary science classroom has been classified in four ways: teaching about computers, teaching with computers, using computers as an assistant (as with simulations and tutorials), and using computers as a tool (recordkeeping, test and worksheet construction, and word processing) (44, chap. 11). In the opinion of some teachers the computer is "the most versatile tool in the science department'' (44, p. 98). One recommended use is to substitute computer-simulated laboratory (CSL) experiences for standard hands-on experiences for nonscience majors in physics classes to increase efficiency of student time and to decrease investments in laboratory equipment and storage facilities (65).

Knight and Dunkleberger (46) studied the attitudes of ninth-graders toward science in an Introduction to Chemistry and Physics course at a Delaware suburban high school. They compared students experiencing computer-managed self-paced (CMSP) instruction and students in a traditional teacher-managed group-paced (TMGP) format. Those in the CMSP sections displayed significantly more positive attitudes toward the study of science than did their TMGP counterparts. And in the schools of Rockville, Maryland, computer use in the Science Career Awareness Training program proved effective in increasing knowledge and interest about science careers for students in grades 4 through 6 (48).

Social Studies

Klassen and Rawitsch (44, chap. 8) identified three major objectives of the social studies that can be enhanced by the use of the computer. First, the computer—at the heart of the technological revolution and one of the most influential developments of the twentieth century—can introduce students to social events and trends. The importance of the computer's role in the current technological revolution ''is reason enough to introduce students to the origins and impact of this mind-expanding device'' (44, p. 66). Second, in introducing them to the social scientist's method of inquiry, the computer allows students to examine larger quantities of information at one time than ever before possible. Third, an understanding of the limits and abilities of computers will be as important to citizens of tomorrow as is an understanding of election processes and group influence to citizens of today.

Computer application to the social studies started rather slowly—and ''computer use in the social studies at the precollege level has remained uniformly low since the first instructional application in the 1960's'' (44, p. 67). Interestingly enough, nearly 90 percent of all social studies teachers (K through 12) report using noncomputer simulations and games, a function the computer might be expected to serve in the future.

As in countless other situations, the relatively inexpensive microcomputer is changing the attitudes of many educators toward social studies application of the technology. As teachers become aware of available computer simulations designed for the social studies, computer use in these classrooms will no doubt increase dramatically. According to Saltinski (69), simulations can be used to involve students in aspects of economics, politics, history, war, and issues dealing with science, technology, and society. And the computer is well suited to acquaint students with the processes social scientists use to formulate their concepts—for example, data gathering, interpretation, inference, classification, observation. As the technology becomes a more common part of the curriculum, aspects dealing with social implications, applications and impact have a logical place in social studies.

In summary, the computer has been used to enhance study in most curricular areas. It has been used to verify existing research and, in some instances, to study its unique impact on certain practices.

Some of the earliest research has been in the area of spelling where the value of such practices as spaced repetition, distributed practice, and forced sequence has been verified. CAI has been shown to produce substantial improvements in certain reading skills including location of multiletter units within words and use of context clues. The computer has also demonstrated its ability to generate individualized reading prescriptions with impressive speed and accuracy.

Computer use in the writing process has also been effective. A valuable tool in editing, the computer shows promise in the teaching and learning of writing skills. It has shown its value in handwriting, giving the user immediate feedback and reinforcement on letter formation and other elements. Furthermore, the considerable effort currently being expended on the writing process will undoubtedly lead to research, much of it on the computer.

The field of mathematics was one of the major contributors to the development of the computer. Possibly more computer-related studies are available here than in other curricular areas. These studies have found the computer to be useful in manipulating numbers, drill and practice, problem solving, and remediation and evaluation.

The computer is yet to establish itself firmly in science and social studies. As in countless other areas, attitudes are changing toward such applications of the technology. With greater teacher awareness of available computer simulations designed for these areas, usage will no doubt increase dramatically. In addition, the computer can help acquaint students with scientific processes and techniques.

Reviews of the research make it evident that the computer has already proved useful in specific areas of the curriculum. Such reviews also indicate contributions that cut across disciplines. Among the most outstanding are contributions to individualized instruction, motivation, and effective use of time.

EXCEPTIONAL CHILDREN

Although the computer is not "all things to all people," it is certainly making its mark as many things to many people. The blind can "read" books by way of speech synthesizers coupled with optical scanners (44, chap. 5). The deaf can communicate by computer over telephone lines. Students who experience frustration and disapproval in their attempts to master specific sets of facts can find the computer a welcome taskmaster, nonjudgmental, and willing to repeat items as long as they request repetition. For the gifted and talented, the computer offers creative minds a new world of challenge.

Boyd (7) used computer simulations designed to motivate low achievers to apply mathematics. The students also used the computer to do calculations, so that they could focus their attention on the important mathematical ideas. The objectives of the study were to determine if (1) with the aid of a computer, low-achieving students could explore mathematical topics previously beyond their reach; (2) the computer might fill a motivation gap; and (3) the precise thinking required in programming might help students to develop problem-solving skills. No significant differences were found in achievement between the computer and noncomputer treatments. However, on an attitude test the noncomputer group scored significantly higher than the experimental group in the areas of general concepts, value, and pleasantness of mathematics.

Most studies indicate that CAI involvement with the learning handicapped is beneficial. For example, Carman and Kosberg (13) considered the variables of math achievement and attention-to-task behavior with emotionally handicapped students using the PLATO Computer-Managed Instruction Program. The experiment demonstrated that the learning rate of emotionally handicapped students could be accelerated by computer-managed instruction, but it failed to show that the accelerated learning rate could be maintained. CAI was, however, shown to have a significant positive influence on attention-to-task behavior.

In another study, Maser (54) and others investigated an alternative approach to individual instruction in basic skills for economically and educationally disadvantaged students at the secondary level. These researchers used CAI in priority areas: arithmetic, language arts, and reading with students "severely deficient" in one or more of these skills. At the end of a three-year period, results indicated that CAI was effective in building basic skills with these students.

Holz and others (40) used CAI to teach basic money-handling skills to trainable mentally handicapped students (ages 7 to 20). The instruction included basic arithmetic skills necessary for handling small amounts of money. These researchers found achievement differences to be statistically significant in favor of the CAI group over the control group.

Other studies lend support to the positive effects of CAI with the learning handicapped. They include Lally's efforts (50) to help retarded children (ages 9 to 14) acquire number conservation skills, and Hasselbring's study (34) of spelling achievement with the learning handicapped. Watkins and Webb (80) also found CAI to be effective in increasing math skills of elementary-level learning-disabled students.

Steele, Battista, and Krockover (75a) studied the effect of computer-assisted drill-and-practice math instruction on the computer literacy of fifth graders of high intellectual ability. They found the computer-assisted approach was just as effective as traditional methods in developing math skills, with the added advantage of developing significant increases in affective and cognitive computer literacy.

Potential for computer use by both gifted and handicapped students appears to be great. The computer has enabled the blind to "read" books and the deaf to communicate over telephone lines. It has also helped handicapped students to stay on task, and it has proved to be a viable tool in helping them develop basic skills. These are but a few evidences of the computer's uses with exceptional children. And once again, its capacities have scarcely been touched.

ATTITUDE AND MOTIVATION

Student interest and motivatio[illegible] . [illegible]mong the greatest challenges in teaching; these elements are basic to stu[illegible] success. In handwriting, for example, practically all new skills have been taught by the time children leave third grade. Progress beyond that grade level depends largely upon the teacher's ability to motivate students. In spelling instruction, keeping interest high appears to be the most essential element (2, pp. 42-43). This is also true in mathematics (83) and other areas of the curriculum.

Studies often report positive student attitudes toward the computer and its educational uses, as well as its ability to motivate and maintain high interest (17). The samples that follow summarize many of these findings.

Robertson (67) found that children who experienced frequent frustration from classroom failure responded positively to the challenge of computer-assisted programs presented on teletype terminals. She concluded that children involved in the study did not seem to have a sense of failure when they made an incorrect response on the teletype terminal. Rather, they reacted as if they were playing a challenging game with an opportunity to try again. Other researchers are reaching similar conclusions. In a study of attitudes toward mathematics of eighth graders receiving CAI and those receiving conventional classroom instruction, Casner (14) found male CAI students significantly more positive about mathematics than non-CAI male students even though these differences did not show up for females.

Attitude surveys about the CARE (Computer-Assisted Remediation and Evaluation) mathematics approach to learning indicated that both students and teachers felt positively toward the system (28). Common teacher responses included—"It's a good individualized program." "It motivates disinterested students." "It proceeds at a student's own rate." Student responses incuded—"You can learn at your own rate." "It's fun." "It's a change from the classroom." "It's easy to understand." "No teacher to yell at you."

Comparing CAI with PI (programmed instruction) as a means of instruction, Johnson (43) found no differences in student achievement, but he found that the CAI group registered a more positive attitude toward their instructional mode than did the PI group. In this case students had been using CAI for almost an entire school year, greatly diminishing chances that differences resulted from the Hawthorne effect.

In a study of the attitudes of a select group of Michigan elementary and secondary teachers and principals, Robardey (66) examined the relationship between attitude and several independent variables with respect to CAI. These variables included knowledge, age, and educational position. Results indicated a significant positive relationship between knowledge of CAI and attitude toward CAI.

In training prospective teachers to be more aware of computers and better prepared to use them, Yueh (85) used CAI with those who were having trouble with mathematics. Students performed as well as they did in a traditional setting, and their comments about computer involvement were favorable.

Studying the effects of student personality on success with CAI, Hoffman and Waters (38) found several traits that seemed to favor such success. They included the ability to concentrate quietly, the ability to pay attention to details, an affinity for memorizing facts, and the ability to stay with a single task until completion.

Among the computer's most valuable potential contributions are its ability to motivate and keep student interest high. Research conducted to date has indicated that student reactions toward certain subjects have been positive in nearly every case as a result of computer use. Excited by its ability to individualize instruction, students see the computer as a useful educational tool, which they consider to be friendly.

LARGE COMPUTER SYSTEMS

Computers are available in three size categories: microcomputers, minicomputers, and mainframes. A major difference among the three types is their capacity to store and process information. With continued development of the microchip and external devices for storing information, such as the disk drive, the differences are becoming less obvious. In spite of these vanishing differences, however, at least two large, well-known systems—both funded by the National Science Foundation—continue to make an impact in education: PLATO (Programmed Logic for Automatic Teaching Operations) and TICCIT (Time-shared, Interactive, Computer-Controlled Information Television).

PLATO

Based at the University of Illinois and marketed by Control Data Corporation, the PLATO system serves hundreds of terminals across the nation, each accessing its memory banks via telephone lines. Its enormous memory capacity and large-scale computing capability enable PLATO to serve these terminals simultaneously and to offer programs that exceed the capabilities of less powerful computers. PLATO can also produce programs with voice and sophisticated graphics including animation. It is perhaps the best known CAI project in the world (33, p. 109) and has been the object of considerable CAI research. A few examples from different educational levels follow.

Stake (75) described a PLATO-based mathematics program in which fourth graders benefited in typing and reading as well as achievement in, and enthusiasm for, mathematics.

In 1980 Mercer University in Macon, Georgia, acquired a PLATO IV learning station (terminal) to determine if students would use it and if student attitudes toward this type of CAI would prove positive (42). Of the several departments with access to the terminal, the heaviest user was the chemistry department. Through computerized simulations chemistry students learned and practiced skills, which they then applied in the laboratory. Overall, the abbreviated trial period demonstrated that students did use the PLATO IV system and that its use generated f vorable attitudes.

Davis (20) reported positive results in both achievement and attitude for students in grades 4 through 6 using PLATO computer math lessons. And Brown's analysis (9) of a field study at three Florida high schools that used the math portion of the PLATO Basic Skills Learning System in remedial courses showed the PLATO system to be both effective and cost-efficient.

TICCIT

The TICCIT system was developed at the University of Texas and Brigham Young University. Using minicomputers, the system, initially designed to provide instruction in English and mathematics (33, p. 110), is capable of handling up to 128 terminals. It automatically keeps records of user progress and types of responses. TICCIT was evaluated by the Educational Testing Service in three environments: community college, university, and an advanced training school for military flight crews (55, pp. 121-27). When used in mathematics courses in community colleges, the completion rate in TICCIT classes was lower than in conventional classes, and fewer TICCIT mathematics students went on to advanced courses. For students who completed the courses, TICCIT required the same amount of study time as conventional lecture sections. In English classes there were no differences between TICCIT and conventional sections, except in some areas lower-ability students did better with TICCIT than with the lecture approach.

Results at the university level were somewhat different. TICCIT students in mathematics classes held their own with those from lecture sections using essentially the same content. English students ranked TICCIT as their first choice as an instructional method, followed by discussion, tutoring, lecture, and home study, in that order. A navy study resulted in an enthusiastic acceptance of CAI training, and participants made slightly better progress with TICCIT than those in a traditional classroom setting.

Overall, students using TICCIT have been found to perform at about the same mastery level as those using other methods. However, students seem to find the system more challenging and usually prefer it to conventional instruction.

The studies cited here are representative of the research that has used PLATO and TICCIT in CAI applications. Such efforts have shown these systems to be effective educational tools that support classroom instruction.

FUTURE ISSUES AND CONCERNS

According to Friedrichs and Schaff (27, p. 106), the new generation must be prepared to take its place in a very different world, one whose shape we can only guess. The substance of these "guesses" will influence the shaping of the future; the accuracy of these guesses will help determine the effectiveness of our efforts to prepare the next generation. Kibler and Campbell (45) likened efforts to determine needed educational changes to an attempt to hit a moving target—it is necessary to aim where it will be, not where it is, judging the speed of the target in relation to the speed of the projectile. As they observed, "We can think of no faster moving target for the lumbering cannon of education to take aim at than computers and their impact on education" (p. 44).

The use of the computer, particularly the microcomputer, is already making a dramatic impact on most aspects of human endeavor. Education is one of the areas now feeling this influence and it will continue to do so. The ability to anticipate the potential use of the computer is imperative. However, in order to maximize future possibilities, an awareness of its past influence and current impact, as well as its potential, is necessary. Armed with this information, educators will then be in a position to make wise decisions about acquisition and future use.

The major purpose of this monograph has been to report data on the educational uses of the computer that have been substantiated by research. Future planning requires an awareness of potential technology, as well as of related issues and concerns. Among the technology already available for use is the videodisc. Issues and concerns include software—its quality and protection; the kind and quality of research; the school's relationship with industry; networking; the training of teachers; and the effect of the computer on formal education.

The Videodisc

A recent technological development, the videodisc is similar in appearance to a 78 rpm phonograph record. It contains prerecorded audio and video information (such as movies or educational programs) that, by use of a player, can be reproduced on a TV set. Among the features that give the videodisc an advantage over the videotape for classroom application are its potential for instant access to a particular part of a program and its ability to produce high-quality still pictures.

Advances in videodisc technology promise to carry the dreams of proponents of individualized instruction a step closer to reality. Many educators will use the videodisc for simulations. Aware of the development of the laser-read videodisc, its versatility with freeze-frame and random access capability, and its interactive capability with computer interface, Schneider predicted, ". . . it will only be a matter of time until videodiscs completely replace conventional motion pictures in educational institutions . . ." (72, p. 54).

In 1981 Glenn and Kehrberg (30) discussed as a reality the technology Schneider viewed as under development in 1976. These authors identified the key issues for users and developers as follows: availability of quality courseware, cost of production, hardware selection, and training of educators. The videodisc is here; educators must explore its application and effectiveness as an instructional tool. An exciting application currently being researched at Brigham Young University in the area of language instruction is interfacing it with the computer (37).

At the present time, educators await the further development of software packages to unleash existing videodisc technology. The advantages are already evident. Only a few years after educators first embraced the videotape, they view the coming of the videodisc to the classroom with equal enthusiasm in 1984. The videotape, however, still claims certain advantages such as local recording capability and tape reusability; therefore it will no doubt have a role in the classroom and in society for many more years.

Software

Major future concerns facing educators using computers include a need for appropriate software or computer programs. The National Education Association's 1982 survey reflected this concern (63, pp. 30-32). The majority of educators responding to the survey expressed dissatisfaction with the amount of available software. Many also expressed concern about software quality. Other issues of consequence to users include software protection with its implications for purchase and use.

Quality Control

The task of controlling the quality of software is of utmost importance. As suppliers attempt to meet the demands for software, products of all kinds are beginning to flood the market. Consequently, it is safe to observe that many products will be of inferior quality. Far too few have been properly researched.

Producers have a responsibility for the quality of their product. However, users exert the greatest influence as they dictate what they will and will not buy. The review and evaluation of software by qualified organizations can assist users to make informed purchasing decisions. For example, CONDUIT, funded by the National Science Foundation and based at the Weeg Computer Center at the University of Iowa, and MicroSIFT (Microcomputer Software Information for Teachers), established by the Northwest Regional Educational Laboratory in Portland, Oregon, and funded by the National Institute of Education, are two agencies currently performing these functions. MECC (Minnesota Educational Computing Consortium), MACUL (Michigan Association for Computer Users in Learning), and the computer program reviews of *Educational Technology* are other types of efforts in this important area.

Software Protection

The illegal duplication of software has become a major issue in the use of microcomputers in education. The way this problem is handled will have a marked influence on software availability. Hoover and Gould (41), after a survey of software producers to explore their concerns about this issue, contended there is much misunderstanding and little clarity about software protection rights. Respondents' opinions ranged from beliefs about mistreatment of software producers to beliefs about inadequate protection of users.

In this survey, the authors randomly selected 68 publishing houses from among 451 that produce software for the Apple microcomputer. Results included the following:

1. Preview:
   Seventy-five percent of the respondents do not allow preview of software prior to purchases. Fifteen percent allow preview and 10 percent did not respond to this item.

2. Return option:
   Forty-five percent allow preview after purchase, with a return option.

3. Copy protection:
   Sixty percent reported that software was not copy-protected.

4. Backup copies:
   Seventy-two percent provide no backup copies. Six percent provide one backup without additional charge. Twenty-two percent provide backup copies with additional charge.

5. Negotiability of special multicopy prices:
   Eighty-two and one-half percent indicated willingness to negotiate

special prices for purchase of multiple copies or a licensing agreement to make multiple copies of programs.

6. Illegal duplication of products by schools:
Thirty-five percent of the producers consider illegal duplication of software by schools to be a serious threat to profits. (41)

The survey authors considered willingness to negotiate special multicopy prices to be the most significant finding of the study. They also expressed dismay that so few software producers were willing to allow schools to preview their products; they suggested that this may be due to the producers' assumption that buyers make copies of programs and then return the originals for refunds.

Problems of the software industry will not be easily resolved. Schools want to buy software, but because of limited budgets they prefer to preview a product before investing in it. Software companies want to sell their product, but they must also protect their huge production investments and marketing costs. A partial solution might be greater adherence to legal and ethical codes on the part of school systems in order to earn the trust of software producers and to encourage more liberal sales policies such as preview privileges and backup copy allowances.

Quality of Research

In addition to quality control for software, another concern is the kind and quality of research conducted in computer education. A serious immediate danger is the possibility that investigators might "jump on the bandwagon" and conduct subquality work. Computer programming requires systematic structure, thus certain questions must be asked when "significant" results are found in CAI research. Are the differences attributable to the influence of the computer on the learning task? Or did the developer use more care in the instructional design than would have been the case without the computer? Also, did the researchers disregard necessary elements of design, implementation, or proper treatment of data? Poorly conducted studies can produce inaccurate findings, causing users to draw misleading conclusions that result in inappropriate applications—a condition that plagues and frustrates serious consumers of educational research.

Relationship with Industry

According to Nathan (61), educators should stop trying to adapt computers to schools and begin adapting schools to fully use computer capabilities. His plea includes rethinking the "where," the "who," and the "what" of education. Consequently he suggested replacing school buildings with community learning centers where K-12 programs, agencies, and businesses could jointly use computers and other technology. In such a setting more equipment could be afforded for each group's use than would be the case if each group had to purchase its own. Under these conditions, capable, technologically oriented people could have joint appointments between high technology companies and schools. Nathan also believes that technological tools, such as television, videotape recorders, and computers, must no longer be "trivialized" in the schools as occasional supplements to classes; they should be fully utilized to help students create and think.

Networking

The idea of networking several computers to a single hard disk drive, such as the Corvus system, is gaining popularity in many parts of the country. Some states and school districts are establishing centers for storing a library of software. As these systems become more sophisticated, the notion of networking expands beyond the school computer lab. Schools, district offices, and state computer centers can share data and software where appropriate by means of telephone lines. These connections provide interschool networks, encouraging interaction in such forms as "electronic mail," sharing of locally written software, and utilization of common data bases. Certain time-sharing systems, such as PLATO (see page 20), have been providing interschool networks with many schools linked to the same mainframe computer. Research is needed in this area.

Teacher Training

A major challenge facing educators involves both pre-servic and in-service teacher training in computer use. Also of concern is both the content and nature of that training. Pre-service needs are evidenced by the computer literacy expected of graduating teachers. In-service needs exist because the majority of current faculty members in educational institutions completed their formal training before the advent of the computer in the school.

Despite much support for teaching computer literacy, there is little consensus concerning its content (10). According to Molnar (58):

> In a field where technological change occurs literally overnight and where computer generations are measured in two to three years, what is literacy? Rapid change is not easily accepted by a profession such as education, which usually measures innovative adoption by generations of teachers and decades of time. (58, p. 28)

Using a panel of experts, all with background and/or experience in both computer science and education, Mikesell (56) explored the possible topics to teach educators in the field of computers. The highest-rated topic was "computer uses and their implications for education." The lowest-rated topics were those related to training educators to be programmers. The panel recommended that educators receive a minimum of 50 hours of instruction and laboratory training.

Although the preceding suggestions are helpful, limited agreement exists concerning ways and means to train teachers in computer use. More light must be shed on this issue before satisfactory answers are in and acceptable guidelines can be established.

Effect on Formal Education

Computer use may assist in breaking down barriers between formal and informal education. According to Friedrichs and Schaff, even though social interaction will continue to play a major part in the educational process, learning at home may become an increasingly important feature of the educational system (27, pp. 106–108). This idea is already a reality in developments such as the

British Open University, which combines home study with summer school sessions that emphasize social interaction. The same authors caution that social interaction is not the only learning area where the computer is an inadequate substitute for the human teacher. Knowledge and information are not necessarily synonymous terms; translating information into a framework of knowledge "requires more complex abilities than mere straightforward transmission" (27, p. 107). Therefore the computer will probably perform better as a tool for the teacher than as a substitute.

After extensive investigation, Gleason (29) made several observations and predictions that illustrate both the challenges and the opportunities for education in the future that have emerged, in large part, as a result of the computer and its potential uses. As educators plan for the future it is well to keep them in mind. They include the following:

1. Dramatic and exciting developments in communications hardware of all types will continue to emerge. Technological developments will remain far ahead of actual application. Schools will work at implementing new technology but will lag behind most other societal institutions.

2. Skills in computer operation will become more a part of the "basics" of education as the computer moves into the home and becomes increasingly important in the industrial world.

3. Neighborhood and home-based learning centers will provide much instruction now provided by the school. Pressure for accountability and competency "will shift from the schools to the individual and possibly to the family."

4. As schools are relieved of some of the burden of teaching content, educators should be able to concentrate more on social interaction, value development, creative thinking, and other objectives now being pushed aside by the back-to-basics movement. While computers will not replace teachers, they may change their role to that of "planning and providing those higher-order learning experiences that cannot be provided by technological devices."

5. The entire concept of learning will undergo a gradual but significant change. "Learning will be living, not just what you do in school." (29, pp. 17-18)

CONCLUSION

Computer research already reported in the field of education is encouraging, and the results are generally positive. Users are motivated and maintain interest over sustained periods of time. As hardware becomes more powerful and less costly, it is reasonable to expect increased educational benefits and continued positive reactions. Similar results can be expected from improved software and from additional technology such as the videodisc.

Despite these encouraging indicators, however, computer use in the schools is not without its problems. The increased efforts of both producers and users are needed to ensure the availability of quality software. First, there must be careful research before mass production, followed by quality control during the production process. Second, guidelines for software protection must be clear and respected.

The roles of the computer in the relationship between education and industry are barely identified, but already they indicate far-reaching potential. Computer use in teacher training and its effect on formal education will likely prove both beneficial and frustrating as future developments materialize.

Another concern directly related to the subject of this monograph is the kind and quality of research conducted. Care must be taken so that the results will be trusted and implemented.

Although the new technology staggers the imagination and offers exciting opportunities, it is well to remember that it offers no guarantees. The computer is only a tool; educators must face the challenge of using its full potential. People are still in control and will determine its use. Therein lies the opportunity as well as the challenge.

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