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ABSTRACT

The impact of the technological revolution on education is examined in this monograph, which focuses primarily on computers. First, the history of the educational uses of a variety of media (film, radio, television, teaching machines, and videodisc systems) is traced and assessed. As instructional aids, it is said, the media economize teachers' time and efforts, impart information efficiently, and can make learning more fun, but research has strongly suggested that the effectiveness of media is largely dependent on the abilities of a good teacher who uses them effectively. Next, the report describes current and emerging applications of the new computer-based technologies, including: (1) management of curriculum content; (2) management of pupil information; (3) presentation and monitoring of drill and practice; and (4) computer-assisted tutorial instruction. Following this discussion, an overview of research on the effectiveness of computers in instruction, and particularly in compensatory education, is presented. Next, difficulties in evaluating cost-effectiveness and feasibility of computer-based instruction are described. Finally, findings on the possible uses of computers in attaining educational equity are discussed. Striking inequities are said to exist between the affluent and the poor; differentials in access to equipment, program quality, and the usages of computers are reported. (KH)

COMPUTER TECHNOLOGY AND EDUCATIONAL EQUITY

By

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PREFACE

It is difficult to overstate the profound effects that media technologies--and especially computers--have had on contemporary life. This monograph examines the impact of the technological revolution on education. Tracing the history of a variety of media before coming to focus on the computer, the authors discuss the roles media have played in schools by imparting information efficiently, saving teachers time and effort, and making learning more fun. Additionally, they question whether traditional conceptions of the effects of media use go far enough. Cognitive psychology suggests that inherent qualities of electronic media change the very nature of the stimuli that promote learning.

Computers in the classroom can be both the vehicle and/or the explicit focus for learning. Professor Gordon and Ms. Armour-Thomas describe a number of present and emerging applications of computer technology. Then, in the final section of the monograph, they bring together data from many sources to present a troubling picture of differences among social groups in terms of access to computers and the kind of learning that takes place with them. It may be, claim the authors, that the enormous educational potential of the computer is being mitigated by inequities in allocation and use.

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THE HISTORY OF MEDIA AND TECHNOLOGY IN EDUCATION

Acquisition of knowledge and the development of intellectual competence have traditionally been the content and process goals of education. Over the last sixty years we have seen increasing use of technological devices to promote these goals with varying success. Conceptual bases for their application changed from notions of media as tools of instruction in which they were used in a supplementary role to the teacher, to notions of inherent structural and symbolic pedagogical attributes of media, facilitating a more central role in instruction. Guidelines for their use emerged from the audio-visual tradition which adopted the physical science concept of hands-on experience or graphic representation as aids to instruction. However, the basis for a technology of instruction was laid as a result of the development and application to instruction of theories of human development and learning and the growing influence of a "systems approach" as exerted on the design and management of teaching and learning transactions. The role of media and technology in teaching and learning has thus advanced from being tangential and supplementary to having shared centrality with content. In fact if we accept the Marshall McLuhan (1967) assertion, the medium may become the message, leaving content in second place.

Films

During the period 1918-24 visual instruction was seen as an alternative to verbal instruction. With the development of still and motion pictures, notions of visual primacy of films over verbal language and the view that pictures provided real, concrete, and meaningful experiences combined to make films an integral part of education in the early part of the century. The characteristics of the visual medium -- the representation of shapes in two and three dimensions, contrasted with the uni-dimensional aspect of verbal language -- were viewed as important attributes of the medium.

Saettler (1968) reviewed some of the major studies on the effectiveness of instructional film during this period and summarized the following:

- while films may be effective in the dissemination of information it is unlikely that any basic change in attitude or behavior would result from their use (Johns Hopkins University Studies, 1919);

- there is no support for the notion that film should be used as a substitute for language but its function should be determined by the nature and function of the instruction. Furthermore, "the usefulness of motion pictures would be enhanced if they were so organized as to confine themselves to their peculiar province" (The University of Chicago Experiments, 1924);

- the use of film may economize time and effort for the teacher but its effectiveness depends on good teaching and the capacity of the medium to contribute to the attainment of the teacher's goals (Yale University Studies, 1928).

Hoban (1969) reviewed over four hundred investigations on film and concluded:

- formal education and age are important variables in quantifying learning from film;
- learning could be facilitated through attention-getting devices (e.g., the use of arrows to highlight certain features);
- redundancy of information -- even the repetition of whole films -- can provide increments in learning;
- active participation of students during film presentation and feedback by teachers on student answers facilitate learning.

Radio

Beginning in the early 1920s instructional radio was used and it was assumed that the aural medium was appropriate for certain types of learning such as music appreciation and the cultivation of listening skills. Potential attributes of the broadcast -- emotional impact, sense of involvement by listeners -- would supposedly contribute to the quality of instructionally relevant content (Forsythe, 1970). Saettler (1968), Skornia (1962), and Wrightstone (1952) describe the emergence and development of instructional radio and report some of the evaluative studies of its effectiveness in education. D. Jamison et al. (1974) reviewed a vast number of evaluations of instructional radio and concluded that imperfect statistical controls, small amount of content via radio, and participation of the classroom teacher confounded the reported claims of effectiveness of a major proportion of the studies. However, the few evaluations that compared radio with other educational resources indicated that instructional radio (supplemented by printed materials, filmstrips, etc.) is as effective in the delivery of most subject matter as is a live classroom teacher or instructional television (ITV).

Television

The commercial introduction of television in the late 1940s paved the way for the application of yet another technological device in education and raised the hopes of educators for a panacea for current ills in education. O'Bryan (1980) describes the two teaching faces of television: instructional television and educational television. The introduction of televised lessons conducted by master teachers and supported by classroom personnel was the response to overcrowding in schools, shortage of teachers, and inadequacy of teacher training. The research in these early days of instructional television focused on the effectiveness of this approach vis-à-vis traditional teachers. Reviews by Schramm (1964) and Kumata (1960) concluded that while television benefited brighter students and those who were motivated to learn in specific content areas, on the whole it was not significantly more effective than face-to-face instruction.

The philosophy behind educational television as "an expander of intellectual horizons and a creator of imagination" (O'Bryan, 1980, p. 11) led to teaching with entertainment as the new rationale for use of television in education, particularly for young children. Novel features such as music, simple narrations, rhyme, and animations were woven into television programming of educational materials so as to entertain children while they learned the three R's. The hope was that the familiarity of these features to young children would make easier the introduction of new information and so increase learning efficiency (Palmer, 1980).

Research efforts were directed to investigation of "the qualities of television as television" (Fowles Mates, 1980, p. 22). Evaluation of prototype productions such as Sesame Street and Electric Company was undertaken in an attempt to identify those program attributes that correlated with children's visual attention. Watkins et al. (1980) reviewed the extensive work in this area and summarized the attributes associated with high and low visual attention. Lively music, animations, slow-paced song and speech, and changes in sound effects were related to high visual attention whereas long or complex speech, men's voices, and live animals were correlated with low visual attention. Evaluation of the educational outcomes of these entertainment-oriented programs did not lead to unambiguous findings. Ball and Bogatz (1970, 1972) claimed that children learned pre-academic skills such as letters, numbers, and relational terms from Sesame Street. A new analysis of the Sesame Street data (Cook et al., 1975) countered that interest and involvement by adults in viewing with young children may have contributed to the gains. Research on Electric Company was also inconclusive. While it was found that children in the primary grades improved in reading competency when exposed to school viewing in conjunction with related curriculum materials, at-home viewing did not contribute to significant increments in learning (Watkins et al., 1980).

Teaching Machines

Skinner (1968) described a teaching machine as a device which arranges contingencies of reinforcement. He advocated its use in teaching on the ground that it contributes to the efficiency of teaching. The emergence of this device in the 1950s (although its roots could be traced to the pioneering efforts of Maria Montessori [1907] and S. L. Pressey [1925]) was an attempt to apply the principles of learning in a laboratory setting to a classroom setting. It is representative of the Socratic method of teaching in which instruction is delivered through a program to the student in small units. The teaching machine also provides automatic feedback on the student's response. Lumsdaine (1960) distinguished three properties of the medium that were different from film, television, or other audio-visual media:

- active student response is continuously required;
- information is provided on each response whether that response is correct or not;
- the student makes self-paced progress through an instructional sequence.

Studies investigating the effectiveness of programmed instruction delivered via the "teaching machine" medium usually compared it to traditional instruction. Reviews by Silberman (1962) indicated that sometimes programmed instruction was superior to traditional instruction and took less time to complete. Some studies saw no significant difference in approaches (e.g., Schramm [1964] and Zoll [1969]).

Video Disc Systems

The latest innovative audio-visual information delivery system interfaced with a computer is the video disc system. It possesses enormous capabilities and if fully exploited may enrich the quality of man-machine interactions beyond the wildest expectations. Some of the more attractive capabilities of this multidimensional and interactive learning system include:

- organization and display of information in multiple modalities: still frames, motion pictures, photographs, transparencies, slides, etc.
- manual or automatic mode of information retrieval
- user control of information (scan, slow forward, search, step forward)
- computer generation of graphic and/or text.

ASSESSMENTS OF MEDIA USE IN EDUCATION

In reviewing research on instructional uses of media over the last sixty years, how well can those uses be seen to have addressed the traditional goals of education? As aids to instruction, they seem to have served a useful purpose in economizing on teachers' time and effort, they have imparted information efficiently, and they have contributed to making learning a fun experience. For the most part, however, whatever role they have played in augmenting learning and in enriching the learning experience of children has been achieved in conjunction with the abilities of a good teacher to use them effectively. Experimental comparisons of media with the classroom teacher have usually borne out the now expected "no significant difference" outcome, leading many researchers to conclude that the medium is not the message and that there is nothing inherently different about media in education that may differentially affect learning (Oettinger and Zapol, 1971; Jamison et al, 1974; Leifer, 1976).

Some researchers, in an attempt to explain the null results, lay claim to methodological flaws such as a low power of statistical design that precluded meaningful evaluation of media research. Admittedly such structural variables do affect educational outcomes and efforts should be made to address them adequately. However, it may well be that the way we have traditionally conceptualized our research questions about media bears little regard to its potential psychological effects and may explain why our questions have led to unproductive answers. What are some of the traditional assumptions about media that have guided research in this area?

Salomon (1979) questioned whether the "holistic" approach to media that views media as invariant entities and media as alternative routes to fixed ends may have led to the inconclusive findings. Recent research findings from cognitive psychology on the idiosyncratic ways that children learn and our increased understanding of the inherent attributes of media and their potential for making a real difference in learning may lead to questions about the validity of traditional assumptions about media in education. Indeed, there is a small but growing body of researchers who have rejected some of the traditional notions of media as invariant discrete entities, or as alternative routes to the same fixed ends, and have posited instead that the unique attributes of media differentially interact with learner attributes leading to different educational ends (Olson, 1974, 1976; Salomon, 1974, 1979; Salomon and Snow, 1968; Salomon and Clark, 1977; Mielke, 1972). More explicitly, from an educational-psychological perspective a medium is seen as possessing a symbol system with peculiar or prototypical attributes (Salomon, 1979) that differentially interact with cognition and learning. Furthermore, the coding elements within a symbol system have the potential to activate certain types of skills, the employment of which can affect learning outcomes. The amount and quality of information extracted by the learner from any one medium is determined by the degree of "literacy" with which the learner actively negotiates with the symbol system of the medium. Certain learner characteristics such as level of competence, cognitive style, and the degree to which the symbol system is isomorphic to the symbolic mode of the pupil's thinking, may determine the level of literacy with which one extracts information.

Meringoff (1980) and White (1983) have added another conceptual idea on learning through electronic media. They claim that the extent to which we learn from a medium should require assessment techniques of learning that are peculiar to that medium. For example, if learning is expected from the presentation of information via television, or computer, media attributes should be maintained by the employment of assessment techniques that are administered electronically (Meringoff, 1980).

Although research studies have addressed these new ideas of media, what is needed is an integrative approach pulling together the many variables in the equation of electronic learning. Gordon and Wang's (1982) conceptual model of learner achievement seems appropriate for incorporating the necessary variables to be studied effectively. More specifically, research on media use in education should consider those clusters of variables associated with learner characteristics, learning conditions, learner behavior, and learner achievement to understand better the way they interact with media to produce learning outcomes.

HOW COMPUTER TECHNOLOGY CAN BE USED IN EDUCATION

The widespread proliferation of computers and computer-related technologies, such as the video disc, made possible by advances in microtechnology, is revolutionizing the ways society generates, obtains, uses, and disseminates information. Ownership and operation of these technologies have been extended to countless homes, businesses, and schools. According to a release from the National Center for Education Statistics (1982), the number of microcomputers in public schools tripled between Fall 1980 and Spring 1982 while there was little change in the number of computer terminals used for instructional purposes. This unparalleled influx of microcomputers in schools is indicative of more widespread and general applications for them than for their predecessors, the mainframe computers which were connected to learning stations via telephone cables. The section that follows examines both conventional and innovative applications as well as those heuristic strategies that reflect the evolving nature of the new computer-based technologies.

Major Applications

Over the years a variety of acronyms have been used to describe the functions of computers in education: Computer-Assisted Instruction (CAI), Computer-Managed Instruction (CMI), Computer-Augmented Learning (CAL), to name a few. More recently, Taylor (1980) used the words tutor, tool, and tutee to categorize the current uses of computers in schools. Diversity of perspectives suggests the difficulty of defining precisely the function of computers in education. Hunter et al. (1975) differentiate tutorial from tool functions, using CAI to describe the former and CAL for the latter. Others have attempted to distinguish the educational CAI from the clerical CMI, but even within the concepts of CAI and CMI there exist divergent views. Splittgerber (1979) defines CAI as a teaching process directly involving the computer in the presentation of instructional materials in an interactive mode to provide and control the individualized learning environment for each individual student. He defines CMI as an instructional management system utilizing the computer to direct the <u>entire</u> instructional process, including perhaps CAI as well as traditional forms of instruction which do not require the computer such as lectures and group activities (p. 20). Baker (1978) views the CAI merely as one of the educational resources managed by the teacher via CMI and claims that CMI is a total educational approach in which a computer-based management information system is used to support the management functions performed by the teacher

(p. 14). Finch (1972) looks at variables such as decision-making requirements, computer/student interactions, and storage for lesson materials and contrasts their functions under CAI and CMI systems. In Taylor's framework of describing the uses of the computer in terms of tutor, tool, and tutee, the tutee function relates to having the student program the computer to perform certain tasks. In this way the student uses the computer to design unique learning environments for herself or himself. This view is popularized in the educational literature and shared by many in the field of educational technology (Papert, 1980; Dwyer, 1975, 1974; Bork, 1977, 1981).

However there are a number of problems in the design and management of teaching and learning transactions which can and should be taken into account in the use of the computer in education. Traditionally problems of learning and teaching have been approached from the two broad perspectives: behaviorism and cognitivism. Although the principles in each domain have gained widespread acceptance, they are somewhat difficult to work out in a classroom setting.

Learning Problems

Proponents of learning from the behavioral tradition focus on connections between the stimulus and the response and the conditions under which such bonds are strengthened or weakened (Thorndike, 1911; Skinner, 1954). From Thorndike's "law of effects" which claimed that behavior which produces a desirable effect tends to be repeated (1927), to Skinner's "contingencies of reinforcement" -- the relations which prevail between behavior on the one hand and the consequences of that behavior on the other (Skinner, 1954), the dominant emphasis has been on the learner's response. Klaus (1965, p. 123) succinctly described the behavioral or connectionist position: "Learning occurs gradually as the probability of certain responses is increased through repeat instances in which a reinforcement or reward follows the occurrence of the response." This conception of learning is difficult to make operational in a classroom of thirty children managed by a single teacher. Skinner (1954) enumerates some of the problems that a classroom teacher faces in establishing optimal conditions which are critical for producing the changes called learning:

- the inability of the teacher to dispense reinforcers frequently
- the inability of the teacher to deal with individual student responses
- the inability of the teacher to reinforce responses consistently
- the inability of the teacher to reinforce student responses immediately (the lapse of a few seconds between response and reinforcement can damage the effect)

However, certain specific programming techniques which are response oriented can be utilized in designing a program that facilitates this type of learning. The linear structure design of some of the early drill and practice programs describes this approach. In such programs the curriculum is organized in unit sequences with no options open to the student but conditions are so arranged as to bring the desired behavior under control.

Other theories from cognitive psychology posit the view of learning that is more stimulus oriented. The potential learner uses his or her previous experiences to interact with the stimulus presentation in a way that is meaningful for him or her: information that promotes thinking, that stimulates his or her imagination. The emphasis is on the quality of presentation rather than on an expression of a "performance." Ausubel (1968) explains that learning is made meaningful or comprehended in the process of internalization when the content of what is to be learned is presented to the learner in final form.

Some of the problems associated with this type of learning have to do with the efficient management of information. Information must be so organized and structured as to ensure effective communication for the learner. Not only must the information be presented in a logical and coherent manner, but feedback on the learner's interactions with the content must both inform the pupil of progress and remedy errors in a meaningful way. A teacher in a regular classroom would be hard pressed to provide such "coach and pupil" interactions for each child in the class.

The capacity of a computer program to utilize an interactive tutorial mode to communicate with the learner presents an efficient way of promoting this type of learning. The programming technique developed by Norman Crowder (1960) simulates a tutor in which programs perform the function of presenting information, questioning the pupil, and providing corrective feedback for incorrect responses. Or the computer can branch to new information once the pupil has evidenced mastery of previous content.

Another area of concern among psychologists from both behavioral and cognitive traditions is the phenomenon of motivation and its role in human learning (Thorndike, 1911; Skinner, 1953; Moore and Anderson, 1969; Lepper et al., 1979). Attempts have been made to distinguish extrinsic from intrinsic motivation although a clear-cut dichotomy has not been empirically validated. Motivation associated with various types of social, material and other reinforcement could be induced by wisely arranging contingencies of reinforcements (Skinner, 1953, 1968). Other theorists prefer to describe motivation that has nothing to do with external reward. They describe the need to develop feelings of efficacy and of competence in handling one's environment (White, 1959). They stress environments that arouse curiosity by being novel, complex, incongruous (Berlyne, 1960, 1965, 1968). Again, there exists the problems of translating these constructs into children's classroom experiences so that a difference is made in their learning.

Malone's (1980) investigations of a series of computer games led him to posit a framework for a theory of intrinsically motivating instruction. Some of the attributes that made computer games appealing were challenge, curiosity, and fantasy. He claims that these should be included in the design of educational computer games for children. But the question whether these attributes would enhance or detract from academic learning remains to be explored (see Table I).

TABLE I

Framework for a Theory of Intrinsically Motivating Instruction

---

I. Challenge

A. Goal

1. Personally meaningful goals
2. Obvious or easily generated goals
3. Performance feedback

B. Uncertain outcome

1. Variable difficulty level
   a. determined automatically
   b. chosen by learner
   c. determined by opponent's skill

2. Multiple level goals
   a. score-keeping
   b. speeded responses

3. Hidden information

4. Randomness

C. Toys vs. tools

D. Self-esteem

II. Fantasy

A. Intrinsic and extrinsic fantasies

B. Cognitive aspects of fantasies

C. Emotional aspects of fantasies

III. Curiosity

Optimal level of informational complexity

A. Sensory curiosity
audio and visual effects

B. Cognitive curiosity

1. "Good form" in knowledge structures
   a. complete
   b. consistent
   c. parsimonious

2. Informative feedback
   a. surprising
   b. constructive

Source: Malone, T.W. "Toward a Theory of Instrinsically Motivating Instruction," Cognitive Science, (4), 1981, p. 357.

Teaching Problems

Schell and Lee (1976) describe instruction as a situation in which an individual intentionally tries to influence the learning of another individual by structuring the environment toward learning. For the student to benefit from instruction, the teacher must not only be responsive to the unique characteristics of the learner but should also be sensitively aware of the environment in which the pupil functions. Furthermore, the teacher must manage that environment in a way that allows the student to behave in a manner that would facilitate his or her achieving the desired outcomes. An effective teacher then is one who is able to do the following with each student:

As regards time --

- maximize instructionally-related time
- minimize assessment-related time
- minimize management-related time (clerical work related to instruction)

As regards tasks --

- diagnose prerequisite skills prior to prescribing instructional treatment
- prescribe instruction based on diagnosis
- monitor the student's progress throughout the instructional process
- evaluate the prescribed lesson
- provide corrective feedback if necessary
- prescribe new treatment if necessary
- structure tasks in terms of levels of cognitive complexity

To carry out all these functions perfectly is beyond the physical and mental capabilities of one individual, no matter how well-intentioned the teacher is. However, the managing capabilities of a computer to collect data, process data, diagnose and prescribe, store data, and report data make it an indispensable tool for any educational system.

Other Variables in Teaching and Learning

Direct Teaching. Kohnin (1970) describes a number of managing behaviors that characterize an effective teacher. Similarly Bennett (1976), Brophy (1979), Rosenshine (1978) and Solomon and Kendall (1979) describe important elements of direct teaching that have important implications for educational outcomes. They include the following:

- effective classroom management; monitoring of children's behavior while engaged in academic tasks
- clarity of stated goals with particular emphasis on sequencing and pacing of materials.
- frequent opportunities to practice and review curriculum materials
- provision of frequent content-related feedback on learner responses
- questions by teachers about student needs
- rewards for student effort and accomplishments.
- variability of teaching methods and modes
- provision of time for learning

The way these variables affect student outcomes calls for the management of the learning environment beyond the mental and physical capabilities of an individual teacher in a classroom of forty children. The structural attributes of the computer can be utilized to manage efficiently the learning environment of children.

Use of Time. The positive relationship between time and learning and instruction is well documented in the educational literature (e.g., Bloom, 1976; Carroll, 1963; Berliner et al., 1978). How much engaged time a student spends on a task, as well as the time teachers use to manage the logistics of instruction, can have important implications for the degree and quality of a student's academic achievement. Again the computer can be used to manage real time efficiently and so as to be beneficial to both teachers and students. In addition, the storage and retrieval capabilities of the computer add greatly to the flexibility of elective time in which the teacher and the student are freed from the time constraints of real time.

CURRENT APPLICATIONS OF COMPUTER TECHNOLOGY IN EDUCATION

An examination of current applications of computer technology in education reveals that some of the problems mentioned above have received more attention than others. Among the most prominent applications are:

- management of curriculum content
- management of pupil information

. presentation and monitoring of drill and practice

. computer-assisted tutorial instruction

In addition a number of other applications, including simulations and computer games, have been developed and are utilized in varying degrees.

Most of the current applications are outlined and their benefits evaluated below.

Management of Curriculum Content

A computer-based system for the management of curriculum content is designed for the implementation of an individualized instructional program. It is the function of such a system (CMI) to manage efficiently the flow of information for all those concerned with the instructional process -- the administrator, the teacher, and the pupil. Baker (1971) describes the primary functions that a computer performs in maximizing the efficient flow of information:

A. Data Collection

The computer collects all data related to instruction -- pre- and post-test scores, units attempted/mastered, objectives attained -- and records it via punched cards or keyboard terminals.

B. Data Storage

Information generated during the instructional process as well as information related to subject matter, curriculum design, educational objectives, placement test instruments, demograhic data on students and so forth are stored in the database and organized in files.

C. Automated Diagnosis and Prescription

Some CMI systems automatically scan students' responses, identify errors or areas of academic weakness, and extract from the database appropriate prescriptions or programs of studies based on the diagnosis. Depending on the system design, implementation of prescriptions can take place on the computer in the form of assisted instruction (CAI) or can be done by the classroom teacher.

D. Data Processing

Computer programs can be created for analyzing organizing, and summarizing data for efficient access.

E. Reporting

The computer can report information at the institutional and course levels of management. At the instructional level, reports are concerned with data such as statistics on placement tests, the number of units completed, etc. At the course level, reports identify the current academic status of individual students relative to the overall curriculum.

Pupil and Curriculum Data File and Retrieval

In the management of an individualized instructional system, information is stored in the database and is categorized into pupil- and curriculum-related files. In addition, the computer can be used to retrieve specific information about student performance in relation to the curriculum as well as the contents of the curriculum itself.

Pupil files. Two types of student-related files can be accessed: student data file and student history file. The first describes the status or demographic characteristics of individual students and the second describes the instructional history of a student: placement test scores, diagnostic and prescriptive information, units mastered, etc.

Curriculum Files. These files contain information on the overall structure of the curriculum plan for a given subject matter and on the instructional segments or units, each associated with prerequisite tasks that must be completed prior to working on the units of instruction, instructional methods, and evaluation measures.

Benefits of CMI. In the management of instruction, the computer can be used to individualize the learning process and optimize each student's learning. It fosters self-direction, responsibility, and independence in learners. It enables the teacher to evaluate alternatives and make decisions based on objective data for the efficient management of instruction. It relieves the teacher from routinized and time-consuming clerical-level duties and provides the opportunity for more personal interaction with the learner. Baker (1978, p. 289) summarizes the potential benefits of CMI systems: (1) they provide the good teachers with the necessary tools for individualizing instruction efficiently and the weaker teachers with well-defined plans and procedures for improvement in their teaching practice; and (2) they regularize curriculum plans and instructional models and force a degree of systematization which cleans up the "sloppiness" in many classroom practices.

Review, Drill, and Practice

The computer program presents a series of exercises to the student to review and practice concepts introduced earlier by the classroom teacher. The computer provides feedback on the student's response and presents more difficult questions once the student demonstrates mastery on previous items. In this mode the computer is used to supplement the role of the classroom teacher.

Benefits of computer drills. Essential characteristics of remedial programs in building and reinforcing basic skills consist of the systematization of presenting learning materials in a logical sequence and in small amounts. They require self-paced instruction and the continuous diagnosing, monitoring, and evaluation of the learner's performance throughout the year. Computer drills can present and manage the kinds of supplementary instruction necessary for the acquisition and consolidation of basic skills in reading, arithmetic, and language ar .

Tutorial Instruction

The computer performs a more direct role in the instructional process. The program introduces concepts. It helps pupils develop skills by questioning, prompting, hinting, explaining, and giving examples. Ideally, it structures the presentation of information that is adaptive to the learner's needs and provides overall guidance of the teaching-learning transaction between teacher and pupil. In this way the computer simulates a human tutor and interacts in a conversational mode in delivering and managing instruction.

Benefits of tutorial programs. The quality of mediation between teacher and learner is a critical factor in facilitating learning. The continuous elicitation of learner response to material presented, and the need to organize, direct, and extend or lift thinking to higher cognitive levels, are some of the characteristics of the functions of mediation in learning (Brainin, 1982). Ongoing research in artificial intelligence and cognitive science is exploring the possibility of programming the computer to behave as an intelligent tutor. Some of these efforts will be highlighted in the "Emerging Applications" section of this paper.

Simulations

A simulation program represents mathematical models which are expressed as a set of equations. The computer calculates the consequences of each input. The user observes how the model changes as a result of such manipulations; models can be represented as words, charts, graphs, or pictures. Some simulation programs exploit the expanded capabilities of the microcomputer to use graphics in the design of games. Often in these programs the computer presents a make-believe world to the child, such as a magical garden in which problems are presented. The user is required to assume a role in that environment, generate hypotheses, make decisions, and observe the consequences of such decisions.

Benefits of simulations. Computer simulations offer a number of advantages to the learner. They provide experiences which are beyond the reach of students but which can enrich their learning (e.g., operating a simulated version of a plane), or promote the understanding of scientific principles too abstract for classroom discussion. Sometimes, experiments are too dangerous to be performed in the classroom, or equipment is too expensive. Simulated experiences can provide the necessary learning without jeopardizing the personal safety of children or wrecking the instructional budget. Roberts (19--) claims that computer simulation games provide children with a sen- - efficacy by allowing students opportunities to practice decision-making by bringing real-world problems into the classroom.

Learning Through Games

Computers can be used to design in a game format activities that can provide intellectually stimulating experiences for children. Banet (1979) and Malone (1980) identified the structural dimensions of computer games that encourage fantasy, challenge, and competition. Attainment of the goal is contingent on skill in speed of response.

Benefits of computer games. Malone (1980) discusses the motivational attributes of video games in terms of their cognitive and emotional benefits. According to him, a game that provides challenge, has a clear goal, has an uncertain outcome, and is personally meaningful fosters self-esteem in the player: it makes the player feel better about her- or himself. The fantasy dimension of a game has an emotionally arousing quality (war, destruction, competition) and also provides a cognitive advantage to the player. Malone claims that the intrinsic fantasy imbedded in games provides an analogy or metaphor as a link or bridge which helps the learner apply old knowledge in understanding new information in the game. In addition, he says, the fantasy provokes vivid images related to the material to be learned and may contribute to its retention. The motivational attribute of curiosity in a successful computer game provides a cognitive benefit to the player. According to Malone, the elements of surprise and the constructive nature of information in feedback motivate a person to learn more, to make his or her knowledge structures "complete, consistent and parsimonious" (p.69). The sensory quality of computer games (changes in light and sound) has an attention-attracting value and enhances initial interest in a game (e.g., circus music at the start of a game).

In addition to the purported cognitive and emotional benefits of successful computer games, some video games require visual motor coordination expertise as well as cognitive skills and strategy in goal attainment. O'Brien (1983) describes the activities in some computer games which promote complex thinking such as analyzing, planning ahead, using a model, and identifying a pattern. Other process attributes of some computer games include estimating angle distances, using positive or negative numbers to move points on a quadrant grid, and making conjectures and testing their validity for problem solution. In summary, computer games provide not only appropriate conditions for learning but activities that stimulate the cognitive capacities in the player.

Instrumental Skill Development

The infusion of computer technology in all walks of life has made it almost mandatory that people develop skills in accessing, processing, and disseminating information via man-machine communication. Word processing information retrieval, and bibliographic research are among the instrumental services provided by the computer.

Word processing. Word processing programs are designed to help users enter texts, revise, edit, store, and retrieve information. Such programs enable users to minimize the tedium associated with composition writing and revising and consequently may contribute to an improvement in writing skills among school children. Some critics worry, however, that this new technology may reduce the need to the writer to hold and manipulate ideas in the head and as a result may ultimately lead to the balkanization of students' conceptual processes.

Information retrieval. Computerized information retrieval systems collect, categorize, and store information which can be coded, abstracted, or indexed in files in a variety of databases. A user can access information by input of simple commands and keywords that describe the subject to be retrieved. Optical scanners connected to digital computers scan, analyze, and report information to the user within a very short time.

Bibliographic research. The computer can also provide to libraries a variety of cataloging services that allow users to access quickly machine-readable cataloging records. The computer can also be used to provide bibliographies with brief or complete citations from records within the library's database.

Student Assessment

Some computer-assisted instructional environments provide computerized versions of traditional paper and pencil tests of academic achievement. The computer presents a series of questions in a multiple-choice format, records and evaluates student answers, and reports the statistical analyses of the results to the teacher or administrator.

The computer can also be used for adaptive assessment of the individual learner. In adaptive testing, successive test items are determined by student responses to previous items. Test items are stratified in a pool structure along a continuum from easy to difficult. The computer scores each item immediately after administration. If the student responds correctly an item from the next higher group or stratum is automatically administered. Conversely, if the item is answered incorrectly, an item in the next lower stratum is administered. This dynamic process in administration continues until the student answers fewer than twenty percent of the items within a given stratum.

Benefits of computerized assessments. Preliminary findings from research on computerized adaptive assessment indicate the following:

- adaptive assessment provides more precise measurement of learner academic ability than do conventional tests

- adaptive assessment improves the quality of achievement test scores by eliminating items that are either too difficult or too easy for the individual learner

- adaptive test battery administers on the average fifty percent fewer items than does conventional test battery

- reduction in testing time provides for a more qualitative use of instructional time and better instructional decision making as a result of increased precision in student test scores

Computerized administration of conventional test batteries, while not as sensitive to individual differences in ability as adaptive measures, relieves the teacher or administrator from the clerical duties of scoring manually each student's test answers.

Computer Programming

Skill in computer programming is fast becoming a major curriculum goal across the nation's schools since the recent advances in microtechnology and the development of artificial languages sufficiently easy for young children to understand. Sippl (1977) identifies five basic components that are fundamental to the development of a computer program:

- a chained group of procedures that describes the overall design of the program (a detailed systems chart or block diagram that takes into consideration the constraints of hardware and software in analyzing the processing required to achieve the specific application)

- the logic and detailed steps by which procedures are processed (usually done through the development of a flowchart)

- the symbolic coding or writing of computer instructions

- translation of the symbolic code into specific machine language for running the program

- the detection and correction of errors that may have occurred in the procedure, logic, or coding phases of program development.

Apart from the translation of symbolic code into machine language that can be conducted by an internal program in the computer, each phase of programming requires both technique and intellectual skill in its development. While the execution of a successful program is dependent on both technique and intellectual skill, a delineation (below) of these components is necessary for a clearer understanding of computer programming.

Technique development. The user must understand the basic concepts or vocabulary of the specific artificial language used for coding information (syntax, commands, punctuation, definitions, etc.). The user must be able to "read" diagnostic messages and develop procedures for tracing and correcting syntax errors. In addition, the user must know how to design the format for storing input on files as well as how to represent the output in a suitable format. Lastly, the user must have general ability to organize, aggregate, and summarize data within the database and retrieve it on demand.

Intellectual skill development. The aspect of skill development in computer programming relates particularly to the development of the logic in the program. While there is little available research on the cognitive processes involved in computer programming, analyses of think-aloud protocols identify the following skills and strategies generally involved in problem solving. Ricardo (1983) developed a measure for predicting programming performance. She claims that computer programming requires the application of inductive and deductive reasoning. According to her, a student uses inductive reasoning to determine the location of an error in a chosen algorithm and deductive reasoning in making decisions in how best to interpret a problem situation. In addition, the student must use logical propositions such as conjuctions and implication and negation in interpreting the problem and testing the algorithm. McKeithen et al. (1981) and Adelson (1981) describe mnemonic strategies that programmers use for organizing information in memory related to the programming problem. Atwood et al. (1980) analyzed think-aloud protocols and described the following general strategies in designing and planning a program:

- separating the problem into its component parts or modules
- generating subgoals
- selecting a possible solution
- "debugging" component parts of the proposed solution

Benefits of computer programming. Those who wish to introduce computer programming into the curriculum claim that children learn by doing: that if a child teaches a machine how to accomplish a task she or he ultimately learns about her or his own thinking (Papert, 1972, 1980; Feurzeig, 1969). Programming acts as an aid to mathematical exploration (Dwyer, 1975; Papert et al., 1979), it promotes insight into certain mathematical concepts (Feurzeig, 1969), and it fosters general problem-solving skills (Papert et al., 1979; Statz, 1973).

Computer Literary

The computer can be used to provide experiential learning on the mechanics of handling information. This can be done in two ways: through the use of canned programs or in the context of a programming language.

Canned programs. Canned programs in computer literacy explain how to enter data and instructions, using a keyboard to process that information and receive results (output) generated by the computer. Among the mechanical information and skills that could be introduced to the user as hands-on experience are the following:

- how to use control characters on the keyboard (use of specific keys to delete, reprint, or display a line, suppress output to the terminal, etc.)
- how to store and retrieve data on disks or tapes
- how to create and edit files in the user's directory
- how to access information from existing databases

Computer literacy through programming. The user learns the basic functions of writing a program -- input information, process information, and output information -- by learning the fundamentals of an artificial language. The user is introduced to the constructs of the language -- commands, values, labels -- and uses these to write simple programs that the computer can interpret and execute. In the event that instructions of the program are "bugged" or incorrect, the user learns the diagnostics for correcting errors. In addition, the user learns commands for editing and storing programs on files and retrieving them when necessary.

EMERGING APPLICATIONS OF COMPUTER TECHNOLOGY IN EDUCATION

Within recent times a new theory has emerged about the way individual children learn. The theoretical principles that undergird packaged programs have not addressed this satisfactorily. Variables used for decision making in packaged programs are based on the mathematical learning models in which the optimal instructional strategy was pursued for maximizing efficiency in learning. However, it is now widely accepted that children learn in idiosyncratic ways and that adaptive instructional strategies should be used to facilitate such learning by adjusting the learning environment to meet the unique learning characteristics of the individual. While there is some flexibility in the design of curricula ultimately the user is bounded by the parameters of the program. Even in those computer-based systems in which diagnostic and prescriptive procedures are used they operate at simplistic levels in that the diagnostic information merely describes the status of the student relative to the structure of the curriculum without specifying the reasons for failure to attain objectives. Such information is necessary. In its absence the prescriptions that follow are subjectively based and may be counterproductive to the best interests of the student.

New Directions

Considerable research is under way in the areas of computer technologies and the design and management of software and courseware to maximize the effectiveness associated with those technologies. "Intelligent" tutors, adaptive computer-based instruction and testing strategies, videodisc systems and microprocessors -- all present great promise for enriching the quality of man-machine interactions.

"Intelligent" tutors. One of the more critical problems in traditional packaged programs is the inherent difficulty of diagnosing student errors and finding more efficient ways of correcting such errors. Packaged programs also may not have adequate teaching strategies to impart information to students who have unique characteristics. The ongoing research in areas of computer science and artificial intelligence is developing prototypes of "intelligent" tutors to mimic the capabilities of an expert human tutor. The components of these programs are: vast knowledge of networks, natural language capabilities, tutoring strategies, and student models. By engaging the student in Socratic dialogue throughout the instructional process, the "intelligent" tutor should minimize some of the problems associated with packaged programs. Brief mention will be made of two programs still in embryonic stages of development but holding promise as paradigms for research in this area (See J.S. Brown and I.P. Goldstein, 1977, for some review).

SCHOLAR is a program designed for teaching facts about South American geography (Carbonell, 1970). Its knowledge network resembles the root system of a tree with the root [illegible] ings below and the trunk above. At each node "importance tags" that pinpoint level of detail are attached to each fact. Heuristically, the tutor composes diagnostic questions to be put to the student and through the "importance tags" feature can answer questions at any level of detail that the student wishes to discuss.

BUGGY is a diagnostic program for helping teachers locate student errors in arithmetic problems (Brown, 1978). The program takes some simple computational task in arithmetic (e.g., adding three double digit numbers) and represents it as a series of subprocedures (e.g., all the numbers in the units column of a problem are listed, as are those in the tens column). The program then runs a series of examples showing a wide range of possible errors that can occur within any subprocedure. In this way the teacher is able to diagnose the underlying cause of student difficulties and therefore clarify misunderstandings about simple rules in arithmetic.

Computer-based instructional strategy. A truly adaptive instructional model is one that is responsive to student performance (both pre-task and on-task) in relation to type of behavior and content required in a learning task (Merrill and Boutwell, 1973). Most management systems in packaged programs are deficient with respect to the management of the learning environment that is adaptive to learner characteristics. Rothen and Tennyson (1978) proposed a computer-based adaptive instructional strategy which utilizes diagnostic and prescriptive procedures for optimizing learning in a dynamically managed environment. The adaptive instructional strategy that they present is a modification of the guidelines for estimating the minimal length of a test (Novick and Lewis, 1973). Briefly, the procedure involves the following:

- estimates of the student's initial performance on each objective in a given set of objectives are obtained;
- estimates of previous student's performances are combined with this unique student's information to generate terminal estimates of the student's probability of mastery of each objective;
- a table of values for varying lengths of test for each objective is thus generated. From the table a definite number of test items can be selected for predicting mastery of each object;
- a definite rule or algorithm selects an instructional prescription from the table of generated values;
- the prescription undergoes continuous updating as the student's on-task learning performance changes.

They claim that the strategy will result in reduced instructional costs and improved task acquisition since prescription of instructional treatment is directly related to the amount of instruction necessary for a given instructional objective.

EFFECTIVENESS OF COMPUTERS IN INSTRUCTION

For a number of reasons it is difficult to estimate accurately the true effect of using computers for instructional purposes. Most studies used an experimental design to investigate the effectiveness of computer delivery of instruction versus traditional methods. In many instances serious methodological flaws in studies' design make findings unclear and inconclusive. Problems emerge with sample size, significant differences in abilities between experimental and control groups, ambiguous treatment of experimental groups, or inappropriate instruments for measuring performance. In some cases reports are anecdotal and focus more on affective than academic outcomes. In other cases, studies are undertaken with no clear conceptual rationale as a basis for investigation. Despite these troubling issues in evaluation, information culled from investigation of computer use in education over a twenty-year period may provide us with general conclusions on the computer's instructional effectiveness.

Recently, Kulik et al. (1983) distinguished two general approaches to evaluation of computer-based educational research. They characterized as "box-score" those reviews that report narratively general trends among various findings and that total up the proportion of those studies that were either favorable or unfavorable to Computer-Based Education (CBE). A second type of review applied a meta-analysis technique to obtain a quantitative synthesis of research outcomes (Glass et al., 1978). Below are general findings from both box-score and meta-analytic reviews as well as specific findings on the instructional effectiveness of computers in compensatory education.

Box-Score Reviews

Generally, studies that investigated the instructional effectiveness of drill and practice application report improved academic achievement for children in elementary schools.

Vinsonhaler and Bass (1972) reviewed 10 major studies that provided 5-10 minute daily sessions of Computer-Assisted Instruction drill and practice in mathematics and language arts and reported performance gains of 1-8 months for children who received CAI over children who received only conventional instruction.

Jamison, Suppes, and Wells (1974) supported the conclusion about the effectiveness of CAI at elementary-school level, particularly for children from economically disadvantaged backgrounds. However, they reported that Computer-Assisted Instruction at the secondary and college level was only as effective as traditional instruction though in some cases it substantially saved student time.

Edwards et al. (1975) reviewed the literature on the instructional use of computers as it relates to learning retention, achievement, and rate of learning. Among their findings they reported that when CAI is substituted for conventional teaching, students showed greater achievement on final examinations but their level of learning retention was not as high as in students taught by conventional methods. In addition, they found that students took less time to learn through CAI than through other methods.

Meta-Analysis Reviews

Kulik et al. (1983) described the general characteristics of meta-analysis:

- the use of objective procedures to find studies (e.g., Psychological Abstracts, ERIC)
- the use of quantitative techniques to describe characteristics of studies and their outcomes
- summaries of overall findings based on appropriate statistical methods

Generally, studies that used the meta-analysis techniques to synthesize findings on Computer-Based Instruction corroborated those from box-score reviews on its effectiveness in raising student achievement, particularly at the elementary school level.

Hartley (1977) investigated CAI in mathematics at both elementary and secondary school levels and found that, on the average, student achievement rose from the 50th percentile to the 66th percentile. Also, she reported that students performed better with this mode of instruction at the elementary level than the secondary school level. However, when she compared Computer-Assisted Instruction with peer and cross-age tutoring and with programmed instruction, she found that the average effect was greater for human tutoring but lesser for programmed instruction.

In a similar type of study, Burns and Bozeman (1981) investigated the effects of CAI mathematics at elementary and secondary schools and found that, on the average, drill and practice programs were more effective in promoting achievement than traditional methods. In addition they found that computer-based tutorial instruction resulted in slightly higher gains than those for drill and practice programs.

More recently, Kulik et al. (1983) analyzed and integrated findings from 51 studies each of which investigated the effectiveness of computer-based teaching in grades 6-12. They focused on five instructional applications: drill and practice, tutoring, computer-managed teaching, simulations, and computer programming. They also integrated the findings on outcomes in six areas: end-of-course examinations, retention examinations, attitude towards the computer, subject matter, quality of instruction, and the amount of time students needed to learn (time on task).

The primary findings of the Kulik analysis were:

- on end-of-course examinations, all CBE students performed at higher levels of achievement than students in conventional classes (i.e., CBE students performed at the 63rd percentile whereas students in conventional classes performed at the 50th percentile on the same exam);
- although scores improved, there were no significant changes reported by studies that investigated retention across intervals from 2 to 6 months;
- generally, studies reported that students expressed a positive attitude towards the computer, subject matter, and quality of instruction in CBE classes;
- instructional time was substantially reduced for students taught with computers.

These findings are consistent with other box-score reviews of CBE research on academic achievement and reduction in instructional time (Jamison et al., 1974; Edwards et al., 1975).

Jamison et al. (1971) reported the evaluation of a drill and practice program in which first graders were given supplementary 10-minute daily drills in mathematics and reading. CAI students showed gains of 1.14 in grade placement compared with 0.26 for the non-CAI students.

Wells, Whelchel, and Jamison (1974) found that 100 sessions of CAI mathematics given daily from 5 to 10 minutes to fifth and sixth graders during the course of the year can raise underachieving students' grade placement by perhaps 0.3 years over what it would have been without CAI.

Similarly, Litman (1973) reported the findings of a CAI program in reading, language arts, and mathematics conducted in 21 elementary schools. He reported that while students made gains of at least one month grade equivalent for each month in the program, greater gains were made in language arts and mathematics than in reading by students who completed more than 100 sessions of work. These gains were substantially better when compared to the national average of students in compensatory educational programs (5.6 months for every 8 months of instruction).

More recently, in an extensive research project that lasted four years, Ragosta et al. (1982) examined the effectiveness of providing 10-20 minute daily sessions of CAI mathematics, reading, and language arts to children from first to sixth grades. Major findings include the following:

- overall, children made significant gains in all areas with daily 10-minute sessions but the gains were greater for mathematics than for language arts reading;
- students showed improved performance during a second and third year of CAI mathematics whereas students maintained but did not increase their gains in reading and language arts with additional years of CAI;
- 20 minutes of daily sessions doubled the gains of students in CAI mathematics.

The reports on the use of CAI at the secondary level are also of a positive nature. Maser et al. (1977) conducted a three-year study in which Computer-Assisted Instruction was provided on a 10-minute daily schedule to strengthen the basic skills of children in secondary schools. They found that CAI combined with good teaching was useful in raising achievement levels particularly for those students in the lower percentile range.

Hirschbuhl et al. (1980) conducted a CAI reading program for seventh and eighth grade students and found that CAI students showed a 2-month growth for every month in the program compared with a 1.4-month gain for non-CAI students. Similarly, Modisett (1980) found that the computational skills of students were improved more when exposed to computer drills than to paper-and-pencil workbook format.

Impact of Specific Computer-Based Instructional Applications

Programs of drill and practice have traditionally been popular in education. The skills that these programs were designed to reinforce were product-oriented (such as counting, ordering, naming in mathematics, and such as defining, describing, or performing basic phonic and structural analysis in reading and language arts). It was relatively easy to program the computer to present information and manage instruction related to these basic skills' acquisition. Consequently, it was not surprising that a major proportion of studies in computer-based research focused on the evaluation of drill and practice application.

However, it is very difficult to program the computer to present and manage information and measure competencies bearing on process-related skills. These skills include applying computational operations for solving problems in mathematics, and inferring meaning, understanding, technique of persuasion, author's attitude, interpretive comprehension, and hypothesis generation and evaluation in reading. More important, there is a dearth of empirically validated research on the nature of process skills and the mechanisms that govern their development. Lacking such a conceptual knowledge base, how can we intervene as teachers and measure the effects of such interventions? In the light of these concerns, the criteria of cost-effectiveness and feasibility become difficult to apply in evaluation of most computer-based instructional applications. Cited below are some implementations of computer-based applications and the problems and issues related to their evaluation.

Tutorial programs. The quality of most existing tutorial programs does not reflect the kind of interactions that are a central component of the teaching-learning transaction. Teaching strategies that are appropriate to the unique learning styles of individual learners -- development of natural language for efficient communication with the learner, monitoring the almost infinitesimal variations in dialogue, the overall moment-to-moment guidance of learning process -- are not essential design features of tutorial programs.

Simulation. Again, the design of simulation does not provide a management for storing student protocol. As a result the program is not able to adapt to subsequent uses of the simulation exercises, dialogue is limited, and teacher intervention is necessary to discuss the effects of student manipulations of variables (Hartley and Lovell, 1978).

Computer-Managed Instruction. Effectiveness in terms of cost and achievement gains is almost impossible to evaluate since the value of CMI lies more in long term improvement in quality of instructional service. How do we measure level of self-direction and initiative in pupils and the quality of teacher-student interaction made possible by an efficiently-run management system? Baker (1971) believes that CMI should be evaluated with respect to its impact upon the role of the teacher since the goals of CMI allow the teacher to be more effective in managing instruction. She further contends that unless effective changes are introduced in the total instructional program it is a lost cause to evaluate CMI in terms of student gains.

Despite these obstacles, estimation of the costs of one successfully-run CMI system (PLAN) can provide some judgment on the overall cost of CMI necessary to support an instructional program at the elementary level. Baker (1971) gauges that the cost of Plan was $42.00 per student in 1975.

Computer literacy. At present there exists a number of perspectives on computer literacy. These views are reflected in the variety of curricula on the subject. Part of the difficulty in deciding on a uniform goal of computer literacy rests with differing educational views on the meaning of literacy. Some claim that it is a specialized literacy and is related to the state of being informed: the level of knowledge one has about computers and the social implications associated with computers. Yet others view it as the ability to communicate efficiently with computers -- a view analogous to language literacy that is concerned with the know-how of reading and writing. It may well be that the question lies not so much in defining precisely "computer literacy" as in asking how can the computer be used as a medium for empowering individuals to learn the necessary skills and knowledge for coping adequately in a society dominated by high technology.

Computer programming. Three projects and learning environments associated with "computer programming" are reviewed below:

A. LOGO projects

Within the last few years, a number of projects have explored the utility of exposing children to computer programming through an artificial language designed for children: LOGO. Under the direction of S. Papert, the MIT LOGO group conducted a series of projects in collaboration with public schools in Massachusetts and Dallas. Other projects were conducted by the New York Academy of Sciences in collaboration with the New York City schools and yet other single projects by the University of Edinburgh and the Bank Street College of Education.

The MIT LOGO group projects comprised a designing and programming environment in which exploratory learning and creativity could flourish. These efforts were directed mainly at observation of learning styles in programming and the degree of programming expertise attained by students in an environment unfettered by the teacher's control of the learning process. The information yielded by these projects, although anecdotal, provided useful insights on students' behavior in a non-traditional learning environment. Reports mainly concerned motivational and social behavior while programming, and described the creative products that emerged from students' interactions with the computer (e.g., high level of cooperative behavior, students acting as LOGO teachers to other students and teachers, ability to argue sensibly about mathematical issues, and diversity of programming styles yielding a wide range of products -- word games, math quizzes, dynamic action games).

More recently Pea (1983, p. 6) carried out a series of evaluative exercises to determine the level of understanding of programming concepts, the degree of programming expertise among children, and the extent to which planning skills developed in a programming environment could be generally applied to other domains.[1] A summary of his findings are presented below:

- while children were able to locate syntactic errors in programs they were unable to find procedural errors;
- children's programs displayed "production without comprehension" and an understanding only by rote of some programming concepts;
- there was inability to follow the sequences of program execution;
- planning skills were not significant when compared with the planning skills of a matched group of non-programming students.

B. SMALLTALK project

This was developed at the Xerox Palo Alto Research Center (Kay and Goldberg, 1977; Goldberg and Ross, 1981). Animated graphic capabilities were used to solve time-distance problems.

C. Project SOLO

This project under the guidance of T. A. Dwyer at the University of Pittsburgh (1974) explored the concept of peer teaching in a BASIC programming environment in which high school children were free to develop programs as they wished.

COST-EFFECTIVENESS AND FEASIBILITY OF CBI

In considering the cost of using computers for instructional purposes, two issues are relevant. First, can the computer provide effective instruction without being economically prohibitive? Cost-effective comparisons of computer use with alternative instructional methods are necessary to answer this question. Second, can the cost of providing effective instruction be constrained within the fixed budget for the provision of alternative instructional services? Estimation of the total cost of resources for providing instruction relative to the amount allocated would determine the answer to the second question. Difficulties in evaluating cost effectiveness or feasibility arise in a number of areas. Major areas are cited below:

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[1] These studies were conducted after a year of programming in LOGO and following the discovery approach to programming advocated by Papert and the MIT LOGO group.

Type of Hardware

The variable cost for both personal microcomputers and time-shared computers makes it difficult to estimate accurately the cost of the hardware. Some personal computers are equipped with a variety of peripheral devices (speech synthesizers, disk drives or cassettes, printers) and prices vary across types of hardware. Similarly, rental costs of time-shared computers and the communication systems that support them are also subject to variable prices.

Courseware

Prices are dependent on the type of instructional application (drill and practice, simulation, tutorial, etc.). The problem becomes more acute when we consider the use of sound-generating and graphic capabilities of the microcomputer in courseware design. Naturally, for every additional "bell and whistle" (auditory and visual effect) there is a corresponding rise in courseware price.

Personnel

Costs for services rendered vary depending on whether personnel are required to supervise or coordinate the implementation of packaged courseware or to provide instruction in an artificial language.

Fund Allocation

The allocations of funds for alternative instructional services are determined by policy decisions at federal, state, and local levels and it is relatively easy to work within these constraints. However, financial contributions for computer applications in schools come from a variety of sources (hardware manufacturers, software dealers, PTA groups) and these variable contributions make it difficult to estimate the economics of computers in education.

Despite these drawbacks, some attempts have been made to estimate the cost of one type of computer-based instruction (drill and practice) for economically disadvantaged children. Jamison et al. (1970) estimated the cost of providing Computer-Assisted Instruction in urban areas and reported that the cost for each student was fifty dollars above the cost of educating a child in a conventional program. However, that figure did not take account of an increased student-teacher ratio as a result of the provison of CAI.

Jamison et. al. (1976) calculated the estimated cost of CAI for economically disadvantaged children in both urban and rural areas. They computed both the add-ons cost (cost estimates of using one thousand terminals in providing CAI to twenty to thirty thousand students) as well as the opportunity costs (the concomitant change in teacher-student ratio that would be necessary to make the provision of CAI feasible). They concluded that CAI was economically feasible when compared with alternative compensatory programs whether costs were computed as add-on or as a substitute for teacher time.

More recently, Levin and Woo (1980) used a resource ingredients approach to analyze the cost of providing computer-assisted instruction at the 1977-78 level of Title I expenditure. They estimated the cost of classroom, personnel, and equipment for operating a CAI laboratory, including curriculum materials and maintenance contracts and supplies, at appproximately $100,000 a year. According to their calculations, one 10-minute session of computer-assisted instruction provided on a daily basis throughout the school year was estimated at $130 using an A-16 minicomputer and 32 terminals. Three 10-minute sessions of drill and practice could be provided for each underachieving pupil with the Title I funds for the 1977-78 period.[2]

Cost-effective comparisons between computer-assisted instruction and alternative instructional methods were unavailable at the time of this report.

COMPUTER TECHNOLOGY AND EDUCATIONAL EQUITY

The advent of the computer and other technologies in education has potential for radically changing the processes by which we teach and learn. The application of the computer in education can be focused on the mechanized and systematic presentation of curriculum content as in programmed text presented via the computer. The computer can be used in the management of student information as was projected by Flanagan (1969) in Project PLAN (Program for Learning in Accordance with Needs). This new technology can be used to manage drill and practice, to mediate learning experiences, to simulate real world or contrived data, and to structure and decontextualize information, as well as to stimulate, motivate, pace, reward, challenge, and monitor learning behaviors. The potential of this technology for changing the way we teach and learn may be limited only by our ingenuity in its application and by our willingness to allocate the prerequisite human and material resources.

It could be fortuitous that these technological developments have occurred concurrently with our nation's increased concern with the achievement of a higher degree of excellence and equity in education. The potential for educational change that may be inherent in computer technology may answer some of the special challenges posed for education by this dual commitment to excellence and equity. Current efforts at coupling these two goals with advances in the educational applications of the computer have not been reassuring. Perhaps more quantity of effort has been expended on problems of educational equity and greater quality of effort has gone toward problems of educational excellence. In addition these different efforts have been expended on different populations -- quantity on the disadvantaged and quality on the more affluent.

[2] Note that these costs are probably cheaper for 1983-84.

The stipulations of the Elementary and Secondary Education Act of 1965 mandated the provision of compensatory education for students who perform below grade level in the basic skills. Since then a number of projects in the public schools have been financed by Title I monies for the express purpose of improving basic skills of underachieving children. The task demands of a basic skills reinforcement program was thought to require a highly structured learning environment in which learning materials are systematically arranged; sufficient opportunity is given for repeated practice; and there are frequent and consistent monitoring and evaluation of peformance. The computer was seen as a responsive educational medium for presenting and managing the kind of instruction so critical for strengthening and consolidating basic academic skills. Over the past twenty years, increasingly the computer has been used in compensatory educational programs designed to achieve a higher degree of equity in the outcomes of elementary and secondary education.

Traditionally, the use of computers in education was restricted to a small group of children who required special attention: remedial programs for the underachieving children and enrichment for the gifted. However, the revolution in microtechnology has ushered an unprecedented number of microcomputers into the nation's schools. With this has come an expansion in the number of instructional applications serving a greater number of children.

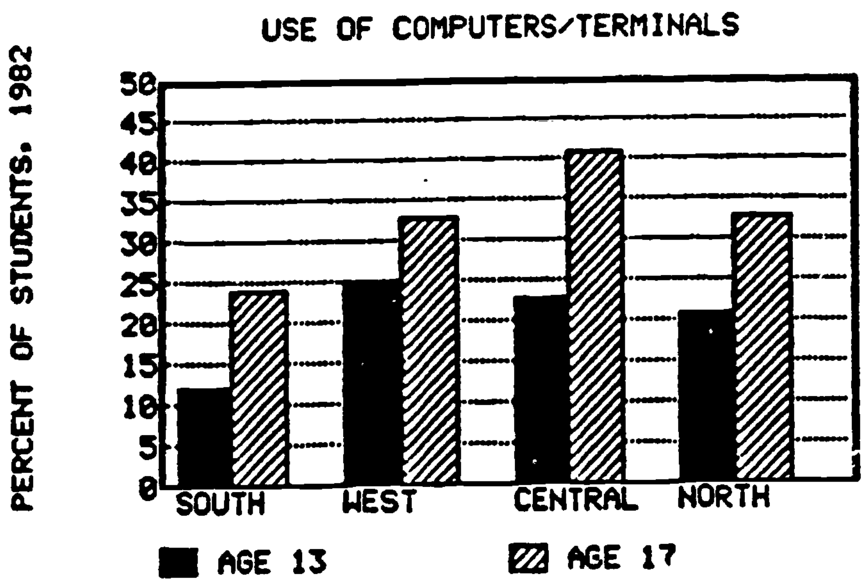
In spite of this expansion, available data point in the direction of differential access to this technology. The 1981 report by Market Data Retrieval and the preliminary (1983) findings from the recent survey initiated by the Johns Hopkins University Center for Social Organization of Schools (CSOS) provide some evidence. The MDR report suggests a relationship between wealth of population in school districts and number of computers in schools. In their 1981 telephone survey of microcomputer use among the nation's school districts, they found that where there was a small number (5 percent) of the population below the poverty line, the number of computers tended to be relatively high (30 percent). Conversely, in those areas where the percentage of people below the poverty line was high (25 percent) there was an inverse relationship to the percentage of computers in the schools (12 percent).

An update on the school market for microcomputers (Hood, 1982) suggests that even though there is still greater access to microcomputers among wealthier schools, there is an increasing growth of computers in less affluent schools because of changes in federal policy. According to this report, changes in Chapter 11 funding have resulted in fewer restrictions on how categorical grants are to be spent and many schools intended to spend part of their block grants on the purchase of microcomputers.

A correlation between wealth and computer access was tentatively reported from the preliminary findings from the survey conducted during the 1982-83 school year by the Johns Hopkins University Center for Social Organization of Schools. In observing the percentage of computers in schools located in relatively affluent districts compared with the percentage used in schools from areas where financial resources are meager, it was found that 66 percent of public schools in affluent districts have access to computers compared to 41 percent in schools located in poorer areas (CSOS, 1983).

More specific statistical information on accessibility of computers and wealth of school districts was reported by Anderson, Welch, and Harris (1983) in a survey of schools. This report claims that the wealthiest schools are four times as likely to have microcomputers as are the poor schools. In observing access by region the report indicates that students in the South have less access to computers than do students in any other part of the country. Figure 1 presents the differences in access across regions.

Figure 1. Regional Access to Computers/Terminals



Source: Anderson, R.E. Welch, W.W. and Harris, L.J. Computer Inequities in Opportunities for Computer Literacy, Minneapolis: The University of Minnesota, 1983.

Many of the national surveys that investigated the instructional uses of the computer indicate that schools use the computer more for computer literacy and programming than for the other traditional applications (drill and practice, tutorials, simulations, etc.).

The findings of the Education Research Service, Inc. (1982) from their nationwide survey "School District Uses of Computer Technology" showed that of those school districts that participated in the survey 64 percent claimed that computer literacy was included in their curriculum, 56 percent used computers for Computer-Assisted Instruction, and 28 percent used computers for Computer-Managed Instruction. In a similar type of survey, the National Center for Education Statistics (1982) examined by grade level the major uses of both microcomputers and terminals for instruction in the 1981-82 school year. The major use of microcomputers was for the teaching of computer literacy (introduction to computer concepts); terminals were used mainly for computer science. Uses varied somewhat across grade levels: secondary schools cited computer literacy and computer science as major uses and elementary schools indicated that basic skills and computer literacy were the more prevalent applications. For further elaboration of specific instructional uses of microcomputers and terminals, see Tables 2a and 2b.

An investigation of the kinds of instructional functions for which microcomputers are used, the CSOS report (1983), indicated that computer programming and computer literacy were the more prevalent functions among secondary schools whereas drill and practice were the primary uses of the computer at the elementary school level. Table 3 presents a breakdown of the reported uses of microcomputers at both elementary and secondary schools. In a summary of estimates of the amount of use of microcomputers in schools, the report showed that typically, at the elementary school level, approximately 40 percent of all instructional time is spent on drill and practice in mathematics, spelling, and language arts; 20 percent is spent playing educational games; and the rest of the time in activities related to computer programming. On the other hand, the typical situation at the secondary school level was that 66 percent of instructional time was spent in programming and computer literacy activities; 18 percent was spent in drill and practice activities; and the rest of the time in playing educational games and other instrumental activities such as word processing.

Anderson, Welch, and Harris (1983) examined the trend of enrollment in programming courses in Title I and non-Title I schools for the period 1978-1980. Their findings suggest that while there is a growing number of students enrolled in computer programming courses across school types, the non-Title I schools show a greater increase. Figure 2 presents programming enrollment trends for 17-year-olds in both types of schools.

On what basis are children assigned to differential computer application? While we are informed about the pattern of growth of computers in schools and instructional applications, we are still relatively uninformed about the type of students who have access to computers and the quality of their man-machine interactions.

Table 2a: Major Uses of Microcomputers for Instruction in the 1981-82 School Year, by Grade Level: United States, Spring 1982

Grade level	Number of Schools with micros	Major uses of microcomputers				
		Compensatory and remedial	Basic skills	Learning enrichment	Computer literacy	Computer science
Total.....	27,501	3,910	5,103	5,174	9,055	6,237
		(In percents of column 1)				
Total.....	27,501	14	19	19	33	23
Elementary...	11,050	18	29	21	29	7
Jr. High.....	5,774	20	11	19	30	10
Sr. High.....	9,504	6	12	18	39	49
Combined and other.....	1,173	19	6	4	34	15

Note: Percents do not add up to 100 since a school can report zero, one, or more than one "Major uses."

Source: National Center for Education Statistics, U.S. Department of Education, 1982, p.5.

Table 2b: Major Uses of Terminals for Instruction in the 1981-82 School Year, by Grade Level: United States, Spring 1982

Grade level	Number of Schools with terminals	Major uses of terminals				
		Compensatory and remedial	Basic skills	Learning enrichment	Computer literacy	Computer science
Total.....	5,898	698	754	1,4[illegible]	1,308	2,005
		(In percents of column 1)				
Total.....	5,898	12	13	24	22	34
Elementary...	959	23	20	28	0	0
Jr. High.....	978	28	10	23	23	14
Sr. High.....	3,620	6	13	21	28	47
Combined and other.....	343	0	0	50	15	45

Note: Percents do not add to 100 since a school can report zero, one, or more than one "Major uses."

Source: National Center for Education Statistics, U.S. Department of Education, 1982, p.5.

Table 3: Reported "Regular" or "Extensive" Uses of Microcomputers

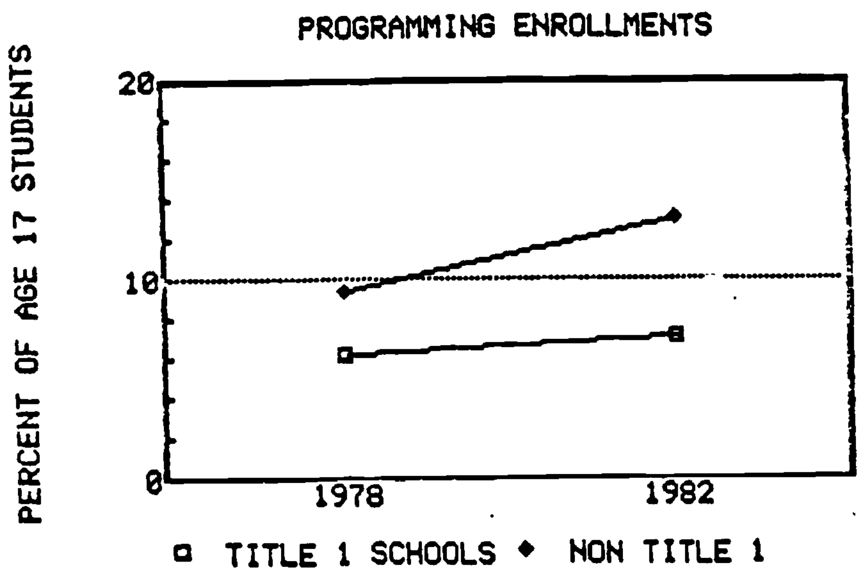
(Percent of teachers reporting such usage at their school.)

ELEMENTARY	PERCENT USING FOR PURPOSE INDICATED	SECONDARY
	85%	Introduction to computers
	76%	Programming instruction
Introduction to computers	64%	
Drill-and-Practice	59%	
Programming instruction	47%	
Tutoring for special students	41%	
	31%	Drill-and-Practice
	29%	Business ed./vocational
	29%	Programming to solve problems
Programming to solve problems	27%	
Recreational games	24%	
	22%	Demonstrations, labs, simulations
Demonstrations, labs, simulations	20%	Tutoring for special students
	19%	Recreational games
	15%	Teacher record-keeping
	14%	Administrative use
Administrative use	10%	Teacher tests, worksheets
Teacher record-keeping	7%	Student papers, word-processing
Teacher tests, worksheets	5%	
Students papers, word-processing	3%	

Source: School Uses of Microcomputers: Reports from a National Survey. Baltimore: Johns Hopkins University Center for Social Organization of Schools, April, 1983, p. [illegible].

Figure 2

Programming Enrollments



Sources: Anderson, R.E., Welch, W.W., and Harris, L.J. Computer Inequities in Opportunities for Computer Literacy. Minneapolis: The University of Minnesota, 1983, p. 4.

One study that went beyond the documentation of information about how schools use computers but focused on problems and issues related to their implementation was one conducted by the Bank Street College of Education (Scheingold et al., 1981). The research team interviewed people at all levels in the school system, from district administrators to students, and observed children's use of computers at both elementary and secondary school level. School systems chosen (assumed names are used) were in Salerno, a large southern city; Granite, a midwestern city; and Greenview, a small northeastern suburban community. Among their findings was one that relates to differential access of computer use at both elementary and secondary school levels.

At the elementary school level in Salerno school district, federal and state compensatory education funding dictated policy decisions about microcomputer use. For those children who performed below average level in mathematics in primary and middle schools, microcomputers were distributed to Title I schools for providing remedial instruction. At Granite and Greenview, while there was no definite policy or funding that restricted access to specific students, community and school efforts (e.g., PTA, Home and School Associations) were responsible for purchasing computers in the schools. Policy decisions in terms of function was determined by the classroom teacher.

At the secondary level, level of ability was used to a large extent as a basis for policy decisions about type of instructional application. In Salerno, computer-related courses were open primarily to those students who showed a high level of mathematical competence. At Greenview, access to computers was provided to learning-disabled students and high achievers in mathematics. Similarly, in Granite, the trend was the same as that at the other sites: the provision of programming-related experiences for those students who were competent in mathematics. This investigation suggests that stronger and weakest students are more likely to be exposed to computers. Remedial work in a basic skill reinforcement is likely for the academically weak and programming-related activities for the more able students.

Against the background of the remarkable developments in computer technology and the information sciences, we are struck by the rather modest application of these developments in education. However, within the limits of what is being applied in education we see striking inequities emerging again between those who have much and those whose needs are greater. The more affluent are more likely to have access to these developments than are students in poorer schools and from low income families. When access to equipment is not the problem, there appear to be differentials in the quality of the programs and the usages of the equipment. The more creative and challenging functions, such as simulation, for which the computer can be used and may be more effective at providing are much more likely to be available to students in affluent situations than to students from situations marked by resource limitations. When we consider the magnitude of the problems of educating the poor, these differentials in access and quality of usage are greatly amplified. Measured against educational need and the potential of this new technology, the advent of the computer in education under conditions reflected in current trends may exacerbate the problems of educational equity, not because of the technology but because of lack of human commitment to educational need.

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