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ABSTRACT

This is the first of a set of four papers on the use of computers in mathematics education. It includes a discussion of the impact of the computer on society, types of computer systems and languages; instructional applications, administrative uses, libraries and data bases, the design of computer-oriented curricula, and cost effectiveness. For the other papers in this series, see SE 016 290 through SE 016 292. (Author/DT)

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THE USE OF COMPUTERS IN MATHEMATICS EDUCATION
RESOURCE SERIES

I. COMPUTER INNOVATIONS IN EDUCATION

by

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ERIC Information Analysis Center for
Science, Mathematics and Environmental Education
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February 1973

THE USE OF COMPUTERS IN MATHEMATICS EDUCATION

RESOURCE SERIES

This is a set of papers and bibliographies addressed to both mathematics teachers and mathematics educators. An introductory paper discusses the general role of the computer in education. A second paper considers the use of computers in what is at present their most widely-used role, as a tool in mathematics problem-solving. A third paper reviews research related to computer uses in mathematics education. A three-part bibliography includes selected references on the general role of computers, on language and programming, and on mathematics instructional applications.

The titles in this resource series are:

The Use of Computers in Mathematics Education:
I. COMPUTER INNOVATIONS IN EDUCATION by Andrew R. Molnar

The Use of Computers in Mathematics Education:
II. COMPUTER-EXTENDED PROBLEM SOLVING AND ENQUIRY by Larry L. Hatfield

The Use of Computers in Mathematics Education:
III. BIBLIOGRAPHY
Part 1. General Educational Role
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Part 3. Mathematics Instruction Applications
A. Teaching About Computers
B. General Uses
C. Tutorial and Practice Modes
D. Problem-Solving Mode

The Use of Computers in Mathematics Education:
IV. RESEARCH ON COMPUTERS IN MATHEMATICS EDUCATION by Thomas E. Kieren

The ERIC Information Analysis Center for Science, Mathematics and Environmental Education is pleased to make these papers and bibliography available.

Jon L. Higgins
Associate Director for
Mathematics Education

Preface

Few mathematics departments in either secondary or higher education have the luxury of a computer set aside for their exclusive use. Instead, the justification for a computer installation is almost always made because of the computer's usefulness in solving and managing a wide variety of educational problems and practices. Thus mathematics teachers who are interested in the use of computers in the mathematics classroom need also to have an overview of the range of other computer applications in education. This paper supplies such an overview.

Originally drafted for a UNESCO conference on the uses of computers in education, Dr. Molnar has included in the paper for this series instructional applications of computers, the uses of computers in libraries and information systems, and computer usage for administrative functions. The paper represents a major synthesis and overview of present computer technology. Since major changes are occurring almost daily in computer technology, the reader must be careful to use such an overview as descriptions of starting points for change, and not as fixed points of stability.

Marilyn N. Suydam
Editor

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COMPUTER INNOVATIONS IN EDUCATION

Education and the Knowledge Society

A wide array of scientific, economic, social and technological factors are reshaping our world and with it, the course of modern education [1, 2].

The Information Explosion

The world is experiencing an information explosion. Approximately 90% of all the scholars who have ever contributed to the body of scientific knowledge are alive today. Dr. J. C. R. Licklider of Massachusetts Institute of Technology estimates that the body of recorded scientific and technical information now has a volume of about 10 trillion (10^{13}) alphanumeric characters (letters, numerals and punctuation marks) [3]. Information is increasing exponentially and can be expected to double in the next 12 years. If a given discipline or specialization could be assumed to contain one one-thousandth of all knowledge, and if a scientist were to read at the rate of 3,000 characters per minute (about the rate at which we read a novel), and if he were to read 13 hours per day for 365 days per year, it would take him 12 years to read everything in his specialty. At the end of this time, he would find that he was 12 years behind in his reading and that the volume of new materials had doubled. Sixty years ago, a scientist would be required to read 25 minutes per day. Twelve years from now, he will have to read continuously, day and night, every day of the year.

The views expressed are those of the author and do not necessarily represent those of the National Science Foundation.

New information has led to the creation of new professions and has made other professions obsolete. Of the children entering school today, it is believed that 70% will work in occupations that do not now exist. This dynamic increase and expansion of knowledge has greatly affected what we teach.

The Post-Industrial Society

Dr. Ralph W. Tyler observes that in 1860, 80% of the labor force in the United States was engaged in the production and distribution of material goods while 20% were providing for non-material needs [4]. Last year he notes that only 40% of the work force was involved in the production and distribution of material goods while 60% were furnishing non-material services. The United States, says Tyler, is the first nation to have developed technology to a point where less than half the labor force is required to furnish material goods. Other nations are also approaching this transition. Tyler also observes that at the turn of the century about 60% of the labor force had little or no education or training, now less than 10% of the jobs available are filled by those with little or no education or training. In short, our society has moved from one based upon industrial production to one based upon knowledge and educated manpower.

Social Factors

Social factors are also affecting the development of modern education. Educational institutions are no longer the sole source of information. Modern telecommunications bring world events instantaneously into the living rooms of families around the world. In the United States over 95% of the families have at least one television set and at the current rate of viewing, it is estimated that the average American youth will spend more time in front of his television set than he will spend in the classroom. This wide array of information has led to a better prepared and more socially aware student.

Another significant social factor is the trend toward a greater democratization of education - providing education for all. The ever-increasing need for an educated populace has led to a significant increase in the number of students entering the educational system. The methods of traditional education, designed to educate the intellectual few, have not proven adequate to cope with the problems of rapidly changing knowledge and large numbers of students with widely varied skills and abilities. Mass teaching, with its lecture method and fixed class schedules, is yielding to a modular curriculum tailored to the needs of the individual. The individualization of instruction which permits students of all abilities to learn and master skills at their own pace, is significantly influencing the direction of modern education.

Technology

The computer as a medium has the potential to meet the needs for individualized learning while meeting the economic necessity of mass instruction. As a tool, with its capacity for handling vast amounts of data, the computer can assist man to manipulate complex ideas and to function at higher cognitive levels of understanding.

In summary, our society is said to be in a transition from being one based upon industrial production to one based upon knowledge. This new emphasis on knowledge, in turn, places greater demands on education. More and more, education is a prerequisite to participation in the knowledge society. Many schools and universities are reevaluating their curricula, examining the needs of their students, and experimenting with the role of the computer in education in an effort to cope with the new demands being placed on modern education.

The Computer and Society

Worldwide Use

The use of computers is worldwide. There are approximately 90,000 general purpose computers in use throughout the world with an estimated value of 35 billion dollars.

The rate of growth of computing has been phenomenal. The first operational digital computer, MARK I, was put into use at Harvard University in 1944. In 1946, the University of Pennsylvania developed the first electronic computer, ENIAC (Electronic Numerical Integrator and Calculator). In 1950, there were only 12 computers in the United States; by 1960, this number had grown to 6,000. Today it is estimated that there are approximately 50,000 general purpose computers in the United States. Another 34,000 computers are located throughout Western Europe, Scandinavia, Japan, Canada, Latin America and the Middle East. The Soviet Union has approximately 5,000 computers and there are another 800 to 1,000 general purpose computers in Eastern Europe. The worldwide computer industry is expected to continue to grow at a rate of 15% to 20% a year until at least 1975 [5].

Computer Applications

The computer is playing a pervasive role in modern society.

Computers are widely used in science, business. industry, government, transportation, law, medicine, engineering and education [6, 7].

In engineering, the computer has speeded calculations and has allowed the rapid development of new products. Computer-aided design has mechanized many aspects of engineering from drawing blueprints to the optimization of material selection. Using a diagram of a planned bridge, the computer works out the stress on each member and prints out the necessary engineering specifications. The architect, using computer-generated displays, can take a tenant on a simulated "walk-through" of the rooms in a newly planned building before it is constructed. If the design fails to meet his needs, the room can be visually redesigned at the terminal and the computer automatically prints out the design changes and the costs of the changes. The computer is used to control precision machine tools in the manufacturing process.

Outer-space research and lunar exploration could not have been achieved without the computer. Computer control systems guide space vehicles to and from their destinations. Photographs of objects in outer space are digitally transmitted back to earth and the computer-enhanced photographs yield clear, high-quality pictures far superior to those obtained using conventional optical methods.

Banks, department stores and business firms are increasingly dependent upon computers to handle day-to-day transactions and record keeping. Bank transactions are punched onto a tape and at the end of the day are automatically transferred by telephone to their proper destinations and automatically stored in a central computer. In food and department stores, computer-based cash registers record all transactions as they occur and automatically order new stock as needed. It is now routine to have computer-generated payrolls where the computer makes the necessary calculati[illegible] for each employee and prints out his payroll check. Credit [illegible] ystems use computers to process transactions. All of these computer-based systems have greatly reduced the time-consuming paperwork involved in trade and commerce.

The collection and rapid analysis of census data using data processing equipment is invaluable in helping governments manage programs in such areas as health, education and welfare.

In transportation, the operation of railroads and the control of land, air and sea navigational systems are now becoming computerized. Traffic control systems offer more efficient use of highways and reduce congestion and the likelihood of accidents. Worldwide hotel and airline reservation systems allow for rapid, efficient scheduling of available resources.

The computer is also used in a variety of other fields. In medicine, the computer is used to monitor and analyze electrocardiograms of heart patients in intensive care wards and to maintain hospital records. Computer-controlled power and chemical plants increase productivity and optimize the quality of the product. It is even possible to buy records of computer-generated music.

The Computer and Education

In the United States, within a relatively short span of 15 years, nearly all universities and more than a third of the four-year colleges provide computing services for research and instruction.

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Approximately 70% of all college students are enrolled at institutions at which there is a computer of some kind for instruction. Another large number of institutions are members of computer networks and have access to a remote terminal on campus. Still others purchase commercial services [8]. A survey of secondary schools in the United States found that 34% of the nation's approximately 23,000 secondary schools have access to and use a computer for administrative and/or instructional uses [9].

The computer is fast becoming a significant tool for instruction. Many major universities are developing courses with the computer for instructional purposes. Courses exist in physics, chemistry, mathematics, digital computing, engineering, foreign language training (French, Spanish, Russian and Chinese), psychology, statistics, economics, management science, medical and biological sciences and many other disciplines. In 1968, a survey by ENTELEK listed 230 instructional programs in the United States [10]. A 1970 survey provides an index of 910 instructional programs [11]. In 1971, Dr. Joseph Denk estimated that there were over 3,000 instructional programs and materials for the computer in a wide variety of academic subjects [12].

Short History of Computers on Campus

A brief description of some of the developments of computers on campus may provide some context within which to interpret the current state of the instructional use of computers in education.

a. The Early Years (1956-1960).

During this early period, universities in the United

States began to acquire computing equipment primarily to assist them in their research activities. The National Science Foundation (NSF), established to support basic research in the sciences, was of major assistance in aiding universities in obtaining computers for academic research. In 1954, in addition to the support for research, NSF began to support activities in science education. Also in that year the U. S. Office of Education (USOE), through the Cooperative Research Act, provided support for research and demonstration in education. In 1958 the U. S. Office of Education under the National Defense Education Act began to provide research on instructional media and educational technology and foreign language education. Consequently, due to federal support the activities during this period were heavily oriented toward computers for scientific research, research on the use of educational technology and foreign language training.

In 1958, the early work on the instructional uses of computers got underway. The Thomas J. Watson Research Center of the International Business Machine (IMB) Corporation demonstrated computer teaching of binary aritimetic. The System Development Corporation (SDC) used a computer as a random-access device for research on branching in a flexible teaching machine. In 1959, the PLATO computer-assisted instruction (CAI) Project was begun at the University of Illinois and was to progress through successive and increasingly more complex systems until in 1964 a large second generation computer was installed to operate PLATO III.

b. The Rise of Campus Computing Centers (1961-1965).

The first extensive use of computers in higher education began in the early 1960's. Distinct organizational units with complex equipment and staff with centrally located facilities began to appear on the college campus. Initial efforts in time-sharing began during this period with a successful demonstration of computer time-sharing at M.I.T. In 1962 two hundred colleges and universities had computers. In 1964 Dartmouth College established a time-shared computer center and opened it to all students and faculty.

During the end of this period, the first systematic research in computer-assisted instruction began in earnest. In 1966, the Institute for Mathematical Studies in the Social Sciences at Stanford University, under the direction of Dr. Patrick Suppes and Dr. Richard Atkinson, began research and experimentation in CAI in elementary mathematics and reading. After initial development, these CAI services were extended through telephone lines to schools over 2000 miles away in the State of Mississippi. The Learning Research and Development Center at the University of Pittsburgh began developing Individually Prescribed Instruction (IPI). Later, the evaluation and monitoring of IPI in the Pittsburgh schools was placed on-line to a time-sharing computer system. The Computer-Assisted Instruction Laboratory at the University of

Texas was established in 1965 and began work on the potential of CAI and its role in college education.

c. Expansion, Refinement and Cooperation (1966-Present).

In research, the need for greater computer capacity led to the installation of large-scale computers on campus. Other efforts focused on providing advanced, on-line interactive computational services for scientific research. By 1969, 1,250 colleges and universities had computers. The Advanced Research Projects Agency (ARPA) began work on creating a nationwide network of heterogeneous computers. The nodes or host computers were interconnected through interface message processors in such a way that every local resource was available to any user in the network. The first nodes were established at a number of universities in 1969 and by 1971, there were 23 active host computers. In 1972, ARPA plans to test the feasibility of extending services to Hawaii and London, England via satellite and cable [13, 14].

During this period the number of centers engaged in research on CAI increased. In the United States, the CAI Center at Florida State University intitated work on applying the systems approach to computers in instruction. The New York Institute of Technology demonstrated the use of computer-managed instruction (CMI). Dr. Lawrence Stolurow in the CAI laboratory at Harvary University studied the psychological and emotional factors affecting instruction in CAI. Other centers at The Pennsylvania State University, the University of California, and The Ohio State University also advanced the applications of CAI in education.

In 1965, under the Elementary-Secondary Education Act (ESEA), schools began a large number of planning and demonstration projects on the uses of computers in instruction. Since a significant portion of this act was concerned with aid to the disadvantaged, many of the computer efforts [illegible] this theme. By 1968 over 155 computer-related projects were initiated at a cost of over 22 million dollars [illegible]

One of the pioneers during the time was the [illegible] District of Philadelphia which developed a wide variety of courses using CAI, computer simulation and games to give students an experience with computers and their use in problem-solving. Today, computing is an integral part of the school curriculum. By 1968, other CAI demonstration projects were initiated in Pontiac, Michigan, the Montgomery County Schools in Maryland and the New York City and Kansas City Public Schools [16].

Another significant development was the establishment of regional computer networks dedicated to instructional purposes. Over the past three years, with NSF assistance, twenty-five regional educational computer networks have been established for the distribution and testing of computer-based instruction within the educational system. This program involves 21 major universities, 206 four-year colleges, 32 junior colleges and 27 secondary schools in 27 different states.

The area of computer science and engineering in colleges and universities has been one of rapid growth. In 1964, there were only 16 institutions offering degree-granting programs. By 1966, the number increased to 30 and by 1970, there were an estimated 55 programs. These programs awarded 1,455 advanced degrees in 1967 and 2,821 in 1969. The Association for Computing Machinery (ACM) was instrumental in the development of many computer science programs through their "Curriculum 68" report which provided recommendations for Academic Graduate and Undergraduate Programs in Computer Science [17].

Since 1965, the U. S. Office of Education has spent approximately 161 million dollars on research and research-related activities, planning projects and operational programs which focus on the applications of computer technology and its use in education. The Office of Computing Activities of the National Science Foundation has spent as estimated 71 million dollars on basic research in computer science, the application of computers in research and computer innovations in education [18, 19].

During this period a number of panels and commissions were established to review the role of computers in education. In 1966, the National Academy of Sciences under the Chairmanship of J. Barkley Rosser made a study of computer needs for research and graduate education in colleges and universities [20]. Since the report did not consider computers for instruction, the President's Science Advisory Committee, under the Chairmanship of John Pierce, was established to study the use of computers in higher education and made recommendations on a program for the support of computers in education [21]. They recommended that computing be made available to all colleges and universities and concluded that an education without adequate computing experience is a deficient education just as any education without adequate library facilities would be a deficient education. In 1970, the Commission of Instructional Technology was established [22]. After a thorough study of instructional technology, the Commission concluded that the past history of one-shot injections of a single technology medium were ineffective and at best offered only optional "enrichment." They observed that technology can carry out its full potential for education only insofar as educators embrace instructional technology as a system and integrate a range of human and non-human resources into the total educational process. The Commission recommended the establishment of the National Institute for Education to conduct research on education and urged that one of the Institutes be a National Institute for Instructional Technology. Currently, the Carnegie Commission on Higher Education, with the assistance of the RAND Corporation, is conducting a study with the aim of making recommendations on the role of computers in instruction [23].

International Activities

The International Federation for Information Processing (IFIP), a multi-national federation of professional and technical societies with a membership from 31 different countries, has established a technical committee for education (TC3) to act as a worldwide clearinghouse for educational materials on the information sciences. In 1965 and 1966, seminars were held in Rome with participants mainly from developing countries on administrative data processing. Other seminars were later held in England, Hungary and France [24]. A working group on secondary school education (WG 3.1) has developed a guide for those who are concerned with planning computer courses for training of teachers [25]. It describes the recommended content of such courses and indicates methods by which concepts of computer science can be explained. In August 1970, IFIP held "A World Conference on Computer Education" in Amsterdam. At that meeting, papers were presented and recommendations were made on computer uses in education.

The Center for Educational Research and Innovation (CERI) of the Organization for Economic Co-operation and Development (OECD) began in 1969 a multi-nation effort on the use of computers in education [26, 27]. Seminars on computers in higher education were held in France (March 1970), Japan (June 1970) and the United States (October 1970), and recommendations were made concerning research and development on computers in instruction. In March 1970, OECD/CERI also held a seminar on computer sciences in secondary education in Sevres, France. OECD/CERI is also providing support for five computer projects in Belgium, France, The United Kingdom, Japan and The Netherlands.

UNESCO has also published "Guidelines for Instructional Use of Computers," based upon a UNESCO consultation with UNESCO officers, experts and consultants in March 1970, in Paris, France. The guidelines have special relevance to developing nations.

The National Council for Education Technology (NCET) held a "Seminar on Computer-Based Learning Systems" at Leeds University in England.

A number of research efforts in CAI were initiated in countries throughout the world [28, 29]. At the University of Bari in Italy, The Center for Studies and Applications of Advanced Technology (CSATA) established a CAI Laboratory. In West Germany, the University of Tubingen has a project on computers in instruction. At Osaka University in Japan, Professor Seigo Tanaka is using CAI in a study of the development of creativity. At the Institute of Pedagogy of Leiden University in The Netherlands, Professor L. de Kierk is conducting research on the implementation of computer-controlled learning in universities and secondary schools. In the United Kingdom, a number of activities are under way. At the University of Leeds, there are activities in the use of CAI in teaching elementary algebra, English as a second language and problem-solving in physical chemistry. Professor G. K. Batchelor of the University of Cambridge is conducting an experiment in which teachers use the computer as an aid in applied mathematics and in understanding physics. Other projects are being conducted at the University of Edinburgh.

In Belgium, Professor A. Jones of the University of Louvain is developing a computer-based, multimedia course in general physics. In France, Professor Y. LeCorre of the Paris Faculty of Science has developed a system of computer questioning in the field of physics.

Computers

Types of Computers

There are two basic types of computers - analog and digital. The analog computer, in a manner similar to a slide rule, uses continuous variable physical quantities such as voltages, forces, and fluid volumes, to represent numbers in calculations. It is used mostly in engineering and the physical sciences, and is convenient for solving differential and simultaneous equations as well as equilibrium and simulation problems. Analog computers account for about 5% of the computers used today. The digital computer is a device that uses binary digits to represent numbers and special symbols in calculation and information processing. By far, it is the most commonly used computer. The hybrid computer is a combination of both a general-purpose digital computer and an analog computer with interface equipment. This configuration takes advantage of the problem-solving speed of the analog machine and the greater precision and programming flexibility of the digital computer.

Input-Output Devices

In order to communicate with the computer, input devices are needed to give instructions, and output devices are needed to display the results of the computer operations. Input devices include punched paper-tape readers, punched card readers or a simple teletype keyboard.

Output devices include teletype-hardcopy, and printers which print alphanumeric information, generate line drawings or even print detailed maps at the rate of 120 characters per line and 30 lines per second.

The terminal is most often an input-output device made up of an alphanumeric typewriter keyboard and a television-like display called a cathode-ray tube (CRT). Frequently a printer is also attached to maintain a record of student-computer interaction or record computer calculations.

More elaborate graphic devices permit the user to interact with the programming in forms other than through a typewriter [30]. Three-dimensional objects can be drawn and displayed on the CRT and rotated in several planes. The computer can determine which surfaces are hidden and should be suppressed and which are to be displayed. A simple instruction permits objects to be readily increased or decreased in size on the CRT. Other devices permit the user to interact with the computer through a photo-sensitive light pen. He simply points to a position on the CRT and the computer detects the action. The computer may print a question on the CRT and the student points to some part on the display or to a super-imposed spot representing "yes" or "no" responses. Other devices use a spot on the CRT as a pointer and the spot is moved by a number of mechanisms, such as a joystick or a mouse. A mouse is a small device which can be moved manually on a horizontal surface near the student and which in turn caused a spot to move on the CRT. Another graphic device is the RAND tablet which is pressure sensitive to the position of a pencil-like stylus. The user may write or draw on the tablet and the information is automatically input to the computer and displayed.

Computer Use

In offline batch processing, the student prepares punched cards or tape and presents it to the computer center. At the computer center the student's program along with other programs are processed sequentially in a batch as time permits. The results are then returned to the student.

In Remote Job Entry (RJE) or on-line batch processing, the student enters his program directly into a terminal. The terminal may be located locally at the central facility or it may be located at some remote site on campus or even at another institution. The terminal is connected through telephone lines to a device that records the information and saves it for processing when the computer is available.

Time-sharing is a procedure whereby the high-speed computer is shared by a number of users simultaneously. Although the computer processes each program sequentially, because of the speed of the computer, it appears as though all users are being handled simultaneously. Interactive systems are those which have conversational aids stored in the computer to assist the user in applying the program. In interactive computing the user has direct control of the program and as instructions are given, the computer responds on a line-by-line basis within fractions of a second.

Programming Languages

A programming language is the means by which a user writes instructions to the computer. It may be highly symbolic or it may resemble a "natural" language. A compiler then translates the user program into a machine language for the computer. FORTRAN (Formula Translation) is a programming language with notations similar to those used in mathematics and is widely used in science. COBOL (Common Business-Oriented Language) is another such language widely used for business applications. COURSEWRITER is a programming language which was designed for writing text and responses for tutorial conversations. BASIC (Beginner's All-Purpose Symbolic Instruction Code), developed at Dartmouth College, is another widely used instructional language which is noted for its simplicity.

Dr. Karl Zinn of the University of Michigan, in an analysis of instructional computer languages, found that there are more than 40 languages and dialects specifically designed for programming instruction [31]. While many of the differences among the languages are trivial, many are real. The differences can be associated with user requirements. Zinn says that there are at least five distinguishable users: instructors, authors, instructional researchers, administrators, and computer programmers.

Instructional Computing Systems

A wide variety of systems and configurations have emerged in applying computing to instruction.

a. Computer Centers.

Colleges and universities, after acquiring a computer, generally establish a central organization with support personnel to operate it and to provide a variety of computing services.

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A recent statewide survey of the colleges and universities in the State of California provides a typical cross-section of computer costs and operational support in higher education [32]. Three-quarters of the 201 institutions surveyed, including medical schools, specialized professional and technical schools and schools of art and music, had computers. The computers were used for adminstration, instruction, library operations, computer science courses and research.

In the 1968 school year, 31.3 million dollars were spent on computing, with 10.5 million dollars of that amount spent for instructional uses. In 1969, this amount increased to 37.8 million, with 12.7 million dollars spent for instructional uses.

Personnel staff providing direct support for computing varied by the type of institution. At the university level, the staff size averaged 15 people (one professional, four programmers and ten clerks and keypunch operators); at the state college level, the average staff size was 6 (one professional, one programmer and four clerks and keypunch operators); at the community college level, the average staff size was 2 (one professional and one programmer-clerk).

While instructional uses of computing are just beginning, it accounted for about 30% of all computing activity. Most institutions used the batch-processing mode. The most frequent instructional use was for data processing, followed by problem-solving, simulation, demonstrations and games, and tutorial. In all, approximately 115,000 students in 3,450 courses use the computer.

5. Cooperative Networks

In the 1960's, with National Science Foundation support, universities and colleges established Regional Cooperative Computer Networks for instructional purposes. A typical network consists of a major university with established computer facilities which provides remote-terminal service to a number of smaller institutions [33,34]. The advantages to the members are immediate access to a large computer with a library of instructional and problem-solving programs and technical and instructional assistance in using the programs. The network also eliminates transfer problems associated with moving instructional programs from one location to another. It also allows for the centralization of and access to large data bases.

A typical example of a regional network is The North Carolina Educational Computing Services (NCES) which services the entire state of North Carolina [35]. It provides interactive teletype computer services to 42 public and private universities, junior colleges and one high school. It provides (1) technical assistance and information services through a catalog of instructional materials, and (2) curriculum development services. It offers workshops, and staff members make periodic visits to the various institutions to stimulate faculty interest in computer-based instruction.

Other networks vary widely in organization and services. The University of Iowa Regional Cooperative Network provides instructional services through remote-batch terminals. The Colorado Educational Computing Network combines an academic television network with a computer network. The Southern Regional Education Board (SREB) is currently conducting an experiment with a group of small colleges to determine the costs and utility of using a mini-computer for instruction and alternatively commercial time-sharing services.

The University of California at Santa Barbara on-line system for computer-assisted instruction in chemistry and engineering is a unique nationwide experiment in the establishment of a disciplinary network [36]. The project was established to evaluate the effectiveness of an on-line system as a tool and to determine its impact upon curriculum. The system is an extended version of the Culler-Fried System and uses an IBM 360/75 computer. User-stations consists of a storage oscilloscope as a graphics output and a dual keyboard for input. There are 50 user-stations in Santa Barbara and additional terminals are located at the Chemistry Departments in Washington State University, University of Minnesota, Beloit College, The University of Pittsburgh, Illinois Institute of Technology, Georgia Institute of Technology, Florida State University, and Louisiana State University. The system provides auto-tutorial instruction, prepared programs and free-form problem solving for complex variables, physical chemistry, control systems and hydrodynamics.

Another variety of network is the Northeast Regional Computing Project (NERComP), which provides access to six major computer centers and networks. Any institution may rent a terminal and pay for only those services used. NERComP provides access to the Massachusetts Institute of Technology MULTICS system, on the General Electric (GE) 645 which is itself a large computer utility; The Brown University IBM 360/67; The Dartmouth College (GE) 635; The University of Massachusetts Control Data Corporation CDC 3800 and CDC 3600; The Bowdoin College Digital Equipment Corporation PDP-10; and The Babson College Hewlett-Packard 200-A. Manuals, which are provided for each system, include a program library of approximately 1,350 programs, language manuals and system commands.

Another approach to sharing computer capacity is the Inter-University Communication's Council (EDUCOM) Educational Information Network (EIN). The EIN System is based on the concept that programs operate most effectively when they are run at the installation where they were created. The network supports the interchange of computational services on a fee basis and in this sense complements rather than overlaps the purpose of most user-groups which only exchange programs. The intital resource of the network is a catalog containing descriptions of programs submitted by EIN members. The programs may be run at the originating installation at rates established by the installation.

Other cooperative efforts involve the creation of user groups. Institutions with similar equipment, computer languages or instructional needs have organized to exchange instructional programs: The Association for the Development of Instuctional Systems (ADIS); The National Association of Users of Computer Application to Learning (NAUCAL); The Association for Computing Machinery, Special interest Group in Uses in Education (ACM-SIGUE); The American Educational Research Association, Special Interest Group (AERA-SIGCAI).

c. Classroom Use

Oregon State University is experimenting with on-line interactive computer graphics system for classroom use in under-graduate physical science classes. The system permits the instructor to dynamically control and vary the parameters, the timing and sequential structure of a demonstration. The system employs a time-shared computer and a computer graphics terminal equipped with a joystick graphic input device. A large screen television projector enables the instructor to display the computer output on a 6 foot by 8 foot screen which is clearly visible for a class of 200 students.

d. Mobile Units

The Pennsylvania State University has developed a mobile CAI unit which is housed in a 40-foot long van with 15 individual student stations each with a computer terminal consisting of a cathode-ray tube display, a light pen, typewriter keyboard, an audio device and an image projector. The van is used to take a computer-assisted remedial education (CARE) course to teachers in rural communities in the State of Pennsylvania. The course is a self-contained, college-level course for in-service teachers of elementary and pre-school children. It is designed to assist teachers to learn to identify and effectively deal with conditions which may affect the school room performance of children who are handicapped, disabled and disadvantaged.

e. Home Delivery Systems

The MITRE Corporation has set-up a demonstration of computer-interactive home-delivery systems [37]. They have combined their Time-shared, Interactive, Computer-Controlled, Information Television (TICCIT) system with a low-cost home terminal to demonstrate the feasibility of using standard television receivers for home computer-driven displays. The computer is located at the MITRE facility in McLean, Virginia and the television sets are located some miles away in the small community of Reston, Virginia. The signals are transmitted from the MITRE facility to Reston by a microwave link and then by cable television (CATV) to the various homes in Reston. The home-user communicates with the computer through his twelve button touch-tone telephone. He receives lessons on the telephone receiver and may also use the touch-tone phone for calculations. The demonstration includes the home use of twenty-seven lessons of fourth grade arithmetic drill-and-practice exercises.

f. Small Computers

One of the more recent developments which is having an important impact on computers in education is the advent of the mini-computer [38]. A computer is small or mini by virtue of its memory size. It usually has a memory of about 8,000 words or less. The range in cost is from $2,500 for a one-user system to $85,000 for a 16-user time-shared system. Configurations allow for a batch-processing system with a card reader, disk storage and printer, a combination of batch- and time-shared services or a total time-shared system. The terminals can be local or remote through the use of telephone lines. Most have the common instructional languages of BASIC and FORTRAN as well as other instructional languages. The mini-computer may be used for CAI, simulations or problem-solving.

Programmable calculators or desk-top computers are being widely used in secondary schools and in departments of engineering and physical sciences at the college level. They range from $1,500 to $6,000 and are easy to use and are portable.

Instructional Applications

Many terms and acronyms have been used to describe the instructional use of the computer: computer-assisted instruction (CAI) computer-aided learning (CAL), computer-based instruction (CBI), and computer-managed instruction (CMI) to name only a few. These terms connote many and frequently overlapping meanings with respect to instructional strategies, equipment configurations, program modes and types of users. Probably the most popular terms are CAI and CMI. Broader terms such as computer-based learning or adjunct uses have evolved to cover activities in which the computer is used as a tool. With the rapid evolution of technology and computer systems, the once-clear distinction among computer management, the use of the computer as a medium and the use of the computer as a tool have become blurred. Today many systems perform all of these functions. There are numerous classification systems to describe the use of computers in instruction. Some examples of instructional use may clarify some of the distinctions.

Drill-and-Practice

The purpose of drill-and-practice is to enable the student to develop a skill or knowledge under controlled learning conditions and then permit him to practice that skill under a wide variety of learning situations. Single frames may present a question with multiple-choice answers. The student responds by typing his selection. The computer may also present a question for which there are a limited number of possible responses. The student may type a word, phrase or sentence. The answer is compared with the anticipated responses. If the answer is correct, the computer responds with an affirmative message and branches the student to new material. If the answer is not correct, the computer branches the student to remedial material. The program usually generates a series of problems for student practice. Records are also kept on student performance.

One notable effort in computer-assisted instruction is the Stanford University Institute for Mathematical Studies in the Social Sciences [39]. In 1965, the Institute began its drill-and-practice program, using one terminal and 41 students. It now services 3,000 students per day in mathematics, reading, spelling drills, Boolean algebra, logic, Russian, and computer programming. Many of the terminals are equipped with digitized audio to provide verbal instructions and responses for the student.

The computer based Russian program was designed to teach first and second year college level courses in comprehension of spoken Russian and the mastery of grammar and syntax. The course has three components: computer sessions, the use of a language laboratory tapes and homework assignments. The CAI students spend about 50 minutes a day, five days a week using a combined audio and teletype format. The teletype keyboard was modified to use a Cyrillic alphabet.

Tutorial

Tutorial programs present a series of factual statements or information and the student may carry on a conversational question and answer dialogue with the computer. The text may have several levels of difficulty and the computer branches the student to the appropriate level depending upon his previous response.

Dr. Alfred Bork of the University of California at Irvine has developed a number of interactive, tutorial dialogues using a graphics terminal in teaching physics [40]. The program provides the student with help hints for solving problems or the student may query the computer for reasonable approaches to a particular problem. Bork uses some of the dialogues to replace certain topics in the lecture or to supplement other classroom work. Another series of dialogues are problem-oriented and designed to assist the student in developing problem-solving skills. Many times, the students lack a mastery of certain mathematical concepts and this tends to interfere with pedagogical development of certain physical theories. Therefore, a series of diagnostic and remedial mathematics dialogues are also used. Finally, dialogues exist which are used in conjunction with simulations of physical systems. For example, students are asked to program lunar landings based upon the physical characteristics of the lunar environment.

Many of the instructional programs at the University of Illinois are of the tutorial mode [41]. The University of Illinois PLATO III System uses a CDC 1604 with 20 graphic-pictorial terminals and has delivered over 70,000 student contact hours of credit courses. The flexibility and simplicity of the TUTOR language permits authors a wide range of strategies and the authors are primarily instructors of all academic ranks. Courses are conducted in electrical engineering, geometry, biology, nursing, library science, pharmacology, chemistry, algebra, mathematics drill, computer programming and foreign languages.

In the life sciences, the student may work with computer-generated genetics experiments, in which he can mate normal and mutant stocks of fruit flies and observe the results which are pictorially presented on a graphic terminal. He may then mate the off-springs and obtain information about particular mutants.

In another lesson in natural selection, the pictorial display presents one light and one dark tree trunk. Randomly displayed on the trees are light and dark moths. The student plays the role of a bird seeking food, and since the student tends to find more dark moths on the light tree than light moths, the evolutionary process is set up. After several simulated moth generations, the change in gene frequencies become evident and the student obtains an insight into the process. In another variation, the effects of air pollution on light bark trees tend to make them darker and consequently more difficult for the student to identify the dark moths. This dramatically conveys the effects that environment can have on genetic development.

Students in the school of nursing study the anatomic and physiologic changes in the body during pregnancy. The computer provides information aids for determining proper nursing strategies and the student may request that certain medical tests be performed. The information derived from such tests is then displayed. Since many medical terms are employed, the student may use a computer-based dictionary for any unfamiliar terms. The lessons force the student to gather and experiment with data, and develop critical thinking skills.

Lessons have been developed to teach programming to second graders. They learn to "walk" a man around the screen by writing simple programs. They program the man to pick up a ball and move it.

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Other exercises that the children perform include a learning maze problem in which they must find and program a safe path through an alligator-infested swamp.

Inquiry Systems

Several experimental courses have been designed to demonstrate the feasibility of learner-controlled, responsive, learning systems.

Dr. Ralph Grubb, using an IBM 1500 with a CRT, has designed a unique course in statistics [42]. The student, as he enters the program, encounters a map of the course displayed on the CRT. On the map is a series of boxes connected in various ways. Inscribed in the boxes are topics or concepts and ways that the student may access them on his route through the program. The student points his light-pen at the box he selects and the screen is erased and a more detailed map of that subsection of the course appears. He may proceed deeper into the subsections, move to successive levels or go laterally to related topics. He may use a keyboard to respond to questions or problems posed by the computer. If he has difficulty with the terms, he may call up a glossary for explanation. If he does not understand the concept, he can go deeper into the structure and get clarification. Grubb describes the approach as being analogous to a network of concepts through which the learner is free to travel.

Dr. Jaime Carbonell of Bolt, Beranek and Newman Inc., has developed a CAI program using the SCHOLAR system to teach the geography of South America [43]. The system applies techniques used in research on artificial intelligence. Conventional CAI is frame oriented; that is, its data base consists of frames of specific text, questions and anticipated answers. By contrast, Carbonell's information-structure oriented CAI utilizes an information network of facts, concepts and procedures as data base. The elements of the network are units of information, defining words and events in the form of multilevel tree lists which literally produce a semantic network. The system can generate text, questions and answers and the student can enter into a mixed dialogue where either the student or the computer can pose questions or respond with answers.

<u>Laboratory</u>

A number of colleges and universities are using computers to supplement or in some cases substitute for laboratory work. Laboratories and laboratory equipment can be very expensive to acquire and maintain. Laboratory experiments may be dangerous and most are time-consuming. If the analytic and procedural functions are separated from the manipulative skills required in the laboratory, one finds that computer-based laboratory experiments can improve learning efficiency and reduce laboratory costs.

In chemistry, Dr. Sam Perone of Purdue University, Dr. E. Klopfenstein of the University of Oregon and Dr. L. Wilkens of the University of Nebraska have developed curricular materials for the use of a mini-computer in an undergraduate analytical chemistry laboratory. The computer augments experiments by allowing more rigorous data analysis and demonstrating the capability for interaction between the computer and experiment. They are now preparing a laboratory handbook based upon their experiences.

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At the University of Illinois, chemistry students perform multiple-step organic syntheses for electrophilic aromatic substitution reactions on the computer [44]. The student may choose any sequence of reactions and the computer displays the product of each reaction. He also learns to identify unknown organic compounds by experimentally performing certain computer-based chemical tests. The computer provides information such as the melting point or by showing the nmr spectrum of the compound. While much of the analysis and experimentation can be performed on the computer, some laboratory experience is necessary to acquire manipulative skills.

Simulation and Games

Simulation is also another effective use of computer instruction. In simulation a model of the real world environment is created in replica or in some analogue form. Simulation eliminates many irrelevant characteristics unrelated to learning, and complex relationships. Time dimensions can be compressed so that events which take many years to transpire in the real world can be presented in weeks or events which occur in very short periods of time can be expanded so that the student can observe the entire event [45].

Dr. Stephen Abrahamson at the University of Southern California has developed a computer simulation with a model having realistic human features for teaching the effects of drugs on body functions. One advantage of such simulations is that medical students studying anesthesiology can practice and learn under realistic conditions without danger or discomfort to a live patient [46].

Dr. Ludwig Braun of the Polytechnic Institute of Brooklyn has developed in the Huntington Computer Simulation Project materials to support high school curricula in biology, physics and the social sciences [47]. The materials are currently being used by 175 teachers and 12,000 students in 80 high schools. In biology they have developed an exercise in resource management based on the life cycle and population patterns of the buffalo and a genetics experiment to demonstrate the statistical nature of the Mendelian Law. In physics, the students learn the operation of a nuclear reactor. A simulation in social studies treats the growth and development of an urban area. Games permit students to test strategies and decision-making in a simulated environment. There are numerous business and economic games used in business schools in many major universities.

Problem-Solving Applications

The instructional uses of the computer which involve problem-solving in a particular academic discipline are numerous. At two recent multidisciplinary conferences on "Computers in the Undergraduate Curricula," over 150 papers were delivered in the following areas: humanities, statistics, engineering, mathematics, economics, biology, physics, accounting, chemistry, social sciences, computer science, business, psychology, and social applications [48, 49]. A recent chemistry conference on "Computers in Chemical Education and Research," heard over seventy papers [50]. Other conferences have been held in physics and the humanities [51, 52].

At the secondary education level, Dr. Thomas Dwyer at the University of Pittsburgh (Project SOLO) is testing the use of a commercial, time-shared terminal and a wide variety of curriculum modules in physics, biology, social science, mathematics and computer science with three secondary schools in Pittsburgh.

Dr. Seymour Papert of MIT using LOGO, a non-numeric computer language, and a control device called a turtle, has been experimenting with teaching children computer-based problem solving [53]. The turtle is a control device with the ability to obey simple commands from a computer and can send signals back to the computer. The turtle can be equipped with a drawing device and can be instructed through a computer program to draw figures. Dr. Papert has demonstrated that average elementary school children are capable of writing programs to draw simple figures, construct complex geometric designs, write a frame-by-frame movie, generate poetry, solve motion problems in physics, and program the movement of a marionette.

The Stanford Research Institute conducted a demonstration of affective learning with elementary school children in grades one through six [54]. Using a CDC 3300 display and several teletype consoles, the children were permitted to move freely among the machines and use programs in mathematics, art, music, botany, poetry, creative writing, abstract problem-solving and physics. The emphasis in this experiment was on teaching self-sufficiency and affective development rather than skills and facts. The computer was used to present a non-verbal experience in thinking without the need for intermediate levels of communication. The computer made it possible for the child to perform activities for which he had not yet developed the mechanical skills, coordination or information.

The computer performed the mechanics and the child used his creativity on such activities as writing and performing a musical symphony.

Computer-Managed Instruction

Computer-Managed Instruction differs from CAI in that in CMI student records and profiles are kept stored in the computer and the student enters test or examination answers or scores. The results of the tests are recorded and evaluated against previous data and a prescription is printed out which directs the student to new materials such as a concept film or a lesson or the computer may provide him with remedial work to improve a detected weakness. Unlike CAI, CMI does not require a large number of terminals, for the student is not necessarily on-line with the computer and the instructional materials are presented in a conventional manner or through other multimedia devices.

In the System Development Corporation's (SDC) Instructional Management System (IMS) used in the Los Angeles School System, tests are given children in which each item is keyed to a teaching objective [55]. The test data are fed into the computer and programs relate student response data to instructional objectives and designate appropriate prescriptive information. If the teacher wants additional diagnostic information or information about materials, she can use the teletype terminal to make additional queries.

Individually Prescribed Instruction (IPI), developed in the Oakleaf School in Pittsburgh, Pennsylvania, uses a system like IMS except the teacher inscribes the performance data on machine-readable forms, which permits a wider range of behavior to be recorded. Another difference is that IPI operates in a completely individualized manner while IMS attempts to accommodate individualized instruction while operating with student groups.

Program for Learning in Accordance with Needs (PLAN), which was developed by the American Institutes for Research, the Westinghouse Learning Corporation and 14 cooperating school systems, uses instructional units which are related to instructional objectives. The units are prescribed on the basis of current student performance and learner characteristics as measured by aptitude tests. The instructional units are broader activities (textbooks, audio-visual material, group projects or tutoring) than those contained in the more detailed prescriptions of the IPI or IMS systems.

The Teacher's Automated Guide (TAG), used in the Portland, Oregon Schools, is a system which permits the storage and retrieval of lesson plans by computer. The teacher inserts a number which represents a given objective and receives a display of the lesson plans appropriate for teaching that specific objective.

In higher education, the Automated Instructional Management System (AIMS) used at the New York Institute of Technology, provides CMI for college level courses in mathematics, physics, electronic technology and computer sciences. At the U.S. Naval Academy, system concepts and behavioral objectives have been applied to develop a number of college level courses which use a multimedia approach and are controlled and monitored through a computer-managed instruction system.

Evaluation and Guidance

The computer is widely used to score and evaluate conventional multiple-choice, paper-and-pencil tests. However, with the computer's ability to rapidly analyze items and branch to other selected items, it becomes possible to design test items with their difficulties tailored to the ability level of the individual. Robert Linn, in a review of a number of theoretical and empirical studies, has undertaken to evaluate the potential of computer-assisted testing. He found that all of the studies, in one way or another, showed that branched computer-assisted tests were superior to conventional paper-and-pencil tests [56]. However, the superiority was not great and only in the extremes of the ability continuum was the branched technique clearly superior. He concludes that the best conventional tests are apt to be as good as or better than branched tests for estimating the ability of examinees over a fairly wide range of ability. He also concludes that large-scale, computer-based testing will probably have to wait for low-cost, large-scale computer-assisted instruction systems.

A number of computer-based guidance and counseling systems have been developed. Probably the most sophisticated one is the Information System for Vocational Decisions (ISVD) developed jointly by Harvard University, The New England Education Data Systems (NEEDS) and the Newton, Massachusetts Public Schools [57]. The student may randomly seek information contained in extensive data files concerning career choice options in occupational educational, military, personal and family living. The files describe current occupational data and the computer predicts conditions for the next ten years. Didactic training on career decision-making is provided through computer-assisted instruction units. Simulation materials are also provided so the student may practice decision-making in games which allow the student to experience the meaning of his decisions about work and the effects of educational decisions under low-risk conditions. After several rounds of decision-making, the computer analyzes the student choices and predicts his likelihood of success. The computer evaluation is based on his risk-taking, his information-seeking, and goal-setting behavior, his time allocation and planning, the adjustment of his program to feedback and his ability to perceive linkages of information between persons and situations.

The American Institutes for Research are developing a computer-based guidance system to complement their individualized instructional system in Project PLAN [58]. They will use data collected on over 400,000 former high school students and follow-up data on their first and fifth year after graduation from high school. A test battery initially administered to the students and correlations between the test scores and success and satisfaction in various occupations will be stored in the computer. The computer will also refer the students to guidance learning units and other materials so that they might become familiar with jobs in a variety of fields.

IBM has developed the Experimental Education and Career Exploration System (ECES) which is designed to help students focus on career goals and the means by which they may be achieved [59].

The system contains a general educational-occupational information library and helps to acquaint the student with the problems of planning a career. It also provides the counselor with information concerning the student's progress in formulating his plan.

The System Development Corporation's (SDC) Vocational Counseling System provides vocational and educational information [60]. It provides probability estimates concerning the success of students in a number of occuptaional fields based upon normative data and follow-up studies. It performs clinical functions, generates reports and monitors student progress.

The systems described attempt to automate vocational and educational information retrieval for students. They tend to be individualized and interactive and they are designed to perform many clerical functions for the counselor. Some offer probability statements based on normative data and the likelihood of success and satisfaction on the job. Most aim at advising students on preparation and planning for a career.

Administrative Uses of Computers

In a survey of computing in public secondary schools, it was found that 30% of the schools were using computers for administrative purposes [61]. A survey of 436 institutions of higher education reported that 53% of the responding institutions were using computers for administrative purposes [62].

Computer Applications

Computers have been used to automate budget and payroll accounts, property management and inventory control, employee and personnel records, and transportation schedules [63, 64]. Information files can be stored on cards, disc or tape and used for a number of data-processing purposes. Personnel files can be used to prepare enrollment rosters, attendance records, grades, or test scores. Separate files may be maintained for comments of teacher or counselors. There is a trend toward the development of total information systems using computerized files that can readily provide both current or longitudinal information on any student, class or school.

The computer is widely used for pre-registration and class scheduling. Flexible scheduling is accomplished by dividing the school day into standard time modules and having the student and instructor indicate available and preferred times for classes. The computer then optimizes the schedule. This tends to produce more free time which can be used for independent study or other school activities.

Other computer uses include test scoring, analysis and reporting. The computer scores the student's paper and calculates his rank and the mean and standard deviation for the class. The teacher may use a pencil to mark the student's letter grade in the appropriate place on a mark sensing card and the computer makes multiple copies and prints the mailing address for each report.

In a survey of state colleges and universities it was found that the most frequent use of computers was for student affairs [65]. Financial affairs was the second most frequent use, physical plant management was third, and general policy planning was last. Most colleges use the computer for registration more than for any other single activity. Computerized space inventories of buildings on campus are used for assigning classroom and office space. Data are also maintained on the costs of construction and operation of buildings and classrooms. Models have been devised to assist administrators in making planning decisions.

One such computer-based planning and budgeting system is CAMPUS [66]. It is a simulation model with related information systems and budgeting techniques designed to help university and college planners understand the impact and cost of planned activities upon their institutions. The system is based upon an input-output model and can be applied to large or small institutions as well as to one institution or a whole system.

CAMPUS was developed in 1964 at the University of Toronto, Canada. It was later used for health sciences planning and then extended by long-distance telephone lines to provide a time-sharing service for a large number of colleges. The decision-maker or planner uses an interactive terminal with a computer-assisted instruction prompter. He calls for simulations or statistical reports from the data base and considers staff space and equipment resources and the demand placed on these resources by such factors as students, program policies and class size. The model considers future trends in enrollment and academic policy and provides information concerning the impact of various decisions.

Centralized Systems

There is a trend toward centralizing computer activities to serve many schools with similar needs within a region [67]. In Oakland, Michigan, one computer center provides pupil accounting and business services for 54 junior and 36 senior high schools within a 900 square-mile area with a total enrollment of 250,000 students. The California Educational Information System is a statewide system which serves the State Department of Education, the Regional Data Processing Center, and local school districts, providing comprehensive pupil and personnel service to over 500,000 secondary and elementary school students. The New England Educational Data System (NEEDS) is a cooperative activity providing record services for schools in six states. The schools may select the services they need and pay either on an itemized per-pupil basis or by option selected.

The University of California Data Processing Services Computer System provides general accounting and payroll and management information for the entire statewide university system.

Management Information Systems (MIS)

The concepts of accountability and cost-effectiveness are permeating the thinking of most colleges and universities. Many schools are changing from line-item, incremental budgeting to input-output models of accounting. Program planning and budgeting techniques are being applied to the management and operation of educational institutions. Essential to this type of activity is a management information system [68].

In order to facilitate this trend, the U.S. Office of Education is supporting the Western Interstate Commission for Higher Education (WICHE) to design, develop and implement management information systems and data bases at colleges and universities. These systems will aid institutions to more effectively allocate resources and will provide them with comparable data on the costs of instructional programs by level of student, course, and field of study.

They will also conduct an educational program including instruction and seminars in systems analysis, operations research, program budgeting, cost-benefit analysis, and the use of simulation models in training administrators in the use of these tools in decision-making.

The primary task will be to establish a standard compatible set of data elements which will be of the greatest practical universality and flexibility so that all levels of institutions and any individual institution can use, on a common and consistent basis, those parts of it of interest to them. Similarly, allowance must be made for suitable aggregation of the data so that they may be used for review purposes at echelons above the campus level.

Van Dusseldorp observes that computerized information systems have mov . through four observable approaches [69]. First, separate, independent computer applications were made without regard for overall information needs. Second, attempts were made to integrate applications by redefining and coding data elements. Third, total systems were designed. Attempts were made to avoid unnecessary duplication in gathering, storing and processing data for separate systems. All information needed by an educational agency was identified. Sources of the necessary data were located and data elements were gathered, stored and processed through a central system. Fourth, the primary emphasis now is to provide information needed for management through management information systems.

Libraries and Data Bases

National Libraries

The United States has three national libraries. The Library of Congress, The National Agricultural Library and The National Library of Medicine [70]. Each has a computer-based automation program.

The Library of Congress Project MARC II (machine-readable cataloging) distributes tapes on a regular basis and has studies underway on input-output terminal devices, optical character readers and mass storage devices. The National Agricultural Library, after completing a study of data-processing needs, is now ready to implement a computer-based system.

In 1964, The National Library of Medicine began its MEDLARS I (Medical Literature Analysis and Retrieval System). Its principal output is an authoritative catalog of citations in the biomedical literature - INDEX MEDICUS. Tapes are regularly sent to a series of regional centers. A biomedical network, MEDLARS II, which was to be operational in 1971, will provide library services, specialized educational services, specialized information services and audio-visual services.

Information Center

The U.S. Office of Education's Educational Resources Information Centers (ERIC) System has now been put on-line [71]. Using a system called DIALOG, it is possible to access 80,000 items through a computer terminal with a 21-inch television screen and teletype

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keyboard. In addition to titles, 200-word abstracts are available. These may also be assessed using the QUERY program, in which category descriptors are used to delimit the selection, or through the monthly guide, Research in Education (RIE). Articles in journals are included in the system; Current Index to Journals in Education (CIJE) is the guide for these. ERIC also provides printed and microfiche copies of educational documents contained in its clearinghouse system.

Disciplinary Information Libraries

The National Science Foundation is supporting the development of a number of disciplinary information libraries [72]. The American Chemical Society, for example, is developing a machine-readable data bank, which will be a unified collection of primary and secondary sources in chemistry. Last year, approximately 240,000 papers and patents were listed in the Chemical Abstracts. These came primarily from scientific journals and approximately 227 other publications. Other disciplinary groups receiving support for science communication systems are: The American Institute of Physics, The American Mathematical Society, The American Geological Institute, Biological Abstracts, Entomological Society of America, The Center for Applied Linguistics, and Engineering Abstracts.

University-Center Information Systems

A number of university-centered information systems with computerized information and retrieval systems have been established [73]. They are primarily in the physical sciences and engineering or are multidisciplinary centers.

The University of Chicago automated its library functions in

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1966 and now has an integrated computer bibliographic data-processing system. They have been able to automate their entire acquisition process through the use of Library of Congress MARC tapes and by inputting other source information through a local terminal.

Regional Library Center

The Ohio College Library Center is a regional on-line cataloging operation which is being designed to generate and operate a union catalog and interlibrary loan system throughout the State of Ohio [74]. It is estimated that approximately $400,000 will be saved at the 50 institutions involved by the second year of operations. The regional approach has several advantages over the institutional center. The computer is selected especially for library use and operations and services are oriented toward the requirements of libraries. Since regional centers have access to all resources it tends to eliminate duplication among libraries and thereby lowers costs and improves efficiency.

Large-Scale, Data Bases

There are a large number of data bases available for analysis. In a survey of social science computing systems, Edmund Meyers was able to identify 23 computer-based systems which are capable of performing simple to rather sophisticated statistical, mathematical, and other forms of analysis [75]. Batch-oriented systems are the most common; however, there are a growing number of interactive systems [76].

The Dartmouth College IMPRESS system is an interactive package for social science instruction and research [77]. Whereas, CAI is highly structured, IMPRESS is totally general. It includes pedagogical routines to guide the novice and is designed so that an undergraduate or beginner will have a high probability of obtaining meaningful data the first time he tries. The system provides 59,256 words in 62 files of social science data and provides most standard statistical routines for analysis. It provides for data storage, data reduction and data analysis. The student may formulate a hypothesis and, using census data and various statistical programs, he can analyze the supporting evidence and determine the validity of his thesis.

The Design of Computer-Oriented Curricula

As more students with widely differing backgrounds have entered the educational process, educators have become more dissatisfied with the traditional techniques of mass instruction. In response to this problem, two significant developments have emerged - the individualization of instruction and the application of the systems approach to the educational process.

Individualization seeks to tailor instruction to meet the needs of the individual. Since modern learning theory was not adequate to prescribe methods to produce individualized instructional materials, researchers began to experiment with new approaches to instructional materials. Today, these developments are having a strong influence on computer-based instruction.

Individualization of Instruction

Cooley and Glazer have defined individualized education as the adaptation of instructional practices to individual requirements [78].

They say that the instructional model operates in the following manner:

a. The goals of learning are specified in terms of observable student behavior and the conditions under which this behavior is to be manifested.

b. When the learner begins a particular course of instruction his initial capabilities - those relevant to the forthcoming instruction - are assessed.

c. Educational alternatives suited to the student's initial capabilities are presented to him. The student selects or is assigned one of these alternatives.

d. Instruction proceeds as a function of the relationship between measures of student performance, available instructional alternatives, and criteria of competence.

e. As instruction proceeds, data are generated for monitoring and improving the instructional system.

Various degrees of automation can be used to implement the model. While it is possible to implement such a system without automation, computer-managed instruction (CMI) can assist the teacher in assessing the student's capabilities and prescribing a course of instruction, or the student can use the computer directly through computer-assisted instruction (CAI). Individualization can operate in any of these three modes - manual, CMI or CAI.

Theory of Instruction

Since group-teaching methods with fixed sets of materials failed to increase the quality of education, researchers began to study the individual learner in an attempt to understand why he succeeds or fails in the learning process.

a. Behavioral Objectives

The stating of instructional goals and objectives and the establishment of performance criteria in behavioral terms has become a central theme among modern curriculum designers. Tests based upon group norms are being supplemented with or supplanted by tests based on performance. The development of a taxonomy of educational objectives by Bloom, Krathwohl and others has influenced the formulation of learning objectives, while Mager's work on preparing objectives for programmed instruction provided the basis for writing behavioral objectives as a form of criterion measure [79, 80, 81].

b. Hierarchy of Learning

Dr. Robert Gagne of Florida State University says that learning materials or tasks can be organized into a theoretical hierarchy of skills and knowledge; learner success or failure is related to his ability to master and integrate subordinate competencies in the hierarchy [82, 83]. The learner's rate of progress is determined by the number and kinds of learning competencies and knowledge that he brings to the situation by his standing with respect to certain basic abilities relevant to the competencies to be acquired in the theoretical hierarchy for the task, and by his level of general intelligence. Therefore, Gagne concludes, if a student fails to perform after a learning program, it is due to several factors. Either some subordinate knowledge may have been omitted or insufficient practice may have resulted in poor recall of a subordinate competency or the program may have been defective in guiding the learner to induce the necessary integration of subordinate competencies.

This position stresses the need for the instructional designer to (1) perform a task analysis in order to identify the learning hierarchy, (2) be concerned for the proper sequencing of learning units and (3) insist that subordinate learning units be mastered before the learner is permitted to progress to the next unit.

c. Rate of Learning

Dr. Leslie Briggs says that is is apparent that just pushing the learner through the program faster is not always a good way to improve learning [84]. On the other hand, self-pacing by the learner is not a universal cure for slow learning. Individual differences in the rate of learning for computer-assisted instruction are far larger than previously thought. Therefore, he recommends the general rule that when individual learning is progressing faster than forgetting, the designer should show all of the material on the first trial. But when forgetting is faster than learning, only one item at a time should be presented.

d. Size of Learning Unit

Briggs finds many conflicting positions when it comes to specifying the size of the step to be used in learning programs[85]. He summarizes the position of a number of learning theorists concerning the size of the step to be used. B.F. Skinner recommends that small steps be used. Jerone Bruner has suggested that huge leaps, with occasional small steps, is the optimum approach. Joseph Scandura recommends abandoning the stimulus-response bond as the basic unit in learning and in its place he would substitute "principles." Sidney Pressey objects to the fractionization of learning into small steps and proposes larger, learner-determined, flexible-size steps. David Ausubel advocates the use of introductory statements in the most general, abstract form to serve as aids to cognitive structuring of subsequent material. Briggs concludes that new techniques are needed to permit the learner to adjust step-size to his capabilities without suffering either from making many errors or being exposed to tedious, unneeded redundancies.

e. Sequencing of Instructional Materials

Should the learner be permitted to control the sequence of materials or should the instructional designer determine the sequence after testing alternative strategies?

In a CAI experiment, Grubb found that merely giving control to the student did not produce significant group post-test gains compared with groups who received the material in a linear manner [86]. In studies at Florida State University involving student control versus computer prescription (CMI) in the sequencing of instructional material, no significant differences were found between the means for four experimental groups [87]. Apparently either approach may be effectively used.

f. Structured Versus Unstructured Learning

Dr. Victor Bunderson of the University of Texas conducted an experiment on structured and unstructured learning situations and found that while some students in the unstructured simulation groups did as well as those in the structured expository groups, they also exhibited extreme anxiety and took much longer to learn the material [88]. Some even gave up on the task. He concluded that while inappropriate for new material, unstructured simulations can be used by a skilled instructor to illustrate complex relationships in context with expository instruction. He advises that simulation should be used after basic concepts and principles are learned in order to integrate them into a meaningful context.

g. Expository Versus Discovery Methods

In an experiment evaluating expository and discovery approaches to learning, Bunderson found that the discovery group required significantly more examples and hence more time to learn than the expository group [89]. His results showed that in the expository group, reasoning ability made little or no difference but in the discovery group it did. Students with low reasoning ability suffered using the discovery method. While the discovery method was efficient and motivating for the brighter student, it placed a burden on other students which the expository treatment did not. In spite of the greater exposure to examples in the discovery group, he found no difference between the groups on a post-test nor on a transfer test. He concludes that for new learning, a carefully programmed expository treatment will be of greater effectiveness than a discovery approach, especially for the less-able student.

The System Approach to the Design of Instructional Materials

Bunderson feels that only through the systematic analysis and design of instructional software can quality materials be developed [90]. First, he says, an analysis should be made of the subject matter and goals should be clearly specified. This will help to eliminate irrelevant material. Second, performance objectives should be specified and a behavioral analysis should be made. This will further specify instructional goals, making them operational and their achievement testable. Third, program architecture should be designed in a modular fashion with each subordinate objective defined as a module with entry conditions established through diagnostic testing and exiting conditions specified through response measures embedded in the module. Fourth, a learning hierarchy should be prepared which shows the prerequisite relationship among modules and points at which subroutine modules may be called. While hierarchical analysis procedures seem applicable to any cumulative subject matter such as mathematics, science or even music, Bunderson cautions that they may be less applicable in highly verbal areas. Finally, through continual cycles of test, evaluation and revision based upon computer-maintained records of student achievement of program objectives, is it possible to improve and ultimately achieve a quality program.

a. System Techniques [91]

In the development of the CAI physics curriculum, Dr. Duncan Hansen of Florida State University applied the systems approach [92].

1. Problems Identification.

Four techniques were used for problem identification. First, a literature search of physics education was made to determine information about student needs and prerequisite abilities. Second, conferences were held with faculty to identify conceptual development of the material, associated problem skills and problems with student motivation. Third, prior test results over a three-year period were studied. Finally, difficult conceptual problems were used to develop a set of problems which were administered to a sample of students in conventional courses. This provided baseline data for comparison during the development of the CAI problems.

2. Task Analysis

A video recording was made of 29 conventional classroom lectures and demonstrations. This provided insight into language appropriate for instruction and pedagogical techniques used by more successful professors. Secondly four currently popular physics textbooks were analyzed for content, sequence of materials and types of practice problems.

3. Entry Behaviors

An empirical assessment was made of the skills and performance of students represented at the entry level. From these results gaps and deficiencies were revealed. Sets of problems were also presented in conventional settings and sample students were asked to solve them. They were assisted until a successful answer was obtained. The approach was found to be successful in focusing on problems faced by students and helped to eliminate much material which seemed necessary from prior reasoning by the professors and the research staff.

4. Behavioral Objectives

The information obtained from course analysis, task analysis and entry level performance was used to formulate behavioral objectives. These were treated as hypothesized propositions which could be achieved by students given effective instructional material. Each objective was in turn broken down into prerequisite skills and concepts.

5. Instructional Strategies

Each assignment was followed by a detailed CAI quiz. If the student failed to meet the criterion performance, he was given remedial assignments and recycled through the quiz items. Concept films and laboratory film presentations were also assigned quiz items.

6. Media Assignment

In media selection the following guidelines were used. First, the use of multiple-sensory input channels were maximized. Second, restricted-sensory channels were used for the acquisition of new information and problem-solving. Third, when problem-solving skill or long-term retention was required, CAI drill-and-practice was maximized. Fourth, evaluation of behavioral objectives was based upon student performance during the CAI portion.

7. Field Tests

The materials were tried out on a sample of students who varied with respect to aptitude, prior knowledge and other psychological considerations. Interviews were held and the comments were used to revise the materials.

b. Empirical Iterative Solutions

Dr. Launor F. Carter of the System Development Corporation reviewed studies of comparisons of different response modes, frame designs, learning reinforcement procedures, teacher roles and sequencing methods. He concluded that, while the studies have often yielded statistically significant results, from a practical point of view, the findings were unimportant [93]. The most important determinant of effective learning, he says, was the quality of the teaching material. Further, Carter concluded that unless the material has been tried out following an "engineering approach" it usually proved ineffective. Carter says that it became apparent that effective materials were not produced by a priori hypothesis-testing experiment. Instead, an interactive empirical procedure was more effective in producing instructional material. They began with the selection of seemingly high-quality initial versions of self-instructional programs in reading, arithmetic, geometry and Spanish. Successive revisions were made until the improved versions were developed which produced the desired standards of performance.

A set of materials was tried with one child at a time. If the child made sufficient errors to warrant assistance, the experimenter then recorded the tutorial technique which seemed most effective. This process of modification was continued until sufficient data were accumulated to warrant a revision of the material. The new version was then tried on other children and again subsequent revisions were made.

The data on revisions were analyzed for consistencies and patterns. Eventually, three hypotheses evolved. First, the "gap hypothesis" led to the explicit inclusion of items necessary to develop prerequisite skills or new skills for criterion performance. For example, in the reading program, they had assumed that if children practiced discriminating between word pairs, they would quickly induce the appropriate letter-sound relationships This did not happen. They had to fill the gap by designing new materials which explicitly demonstrated letter-sound relationships included in the program. They also found that when children learned to sound out and read words in the program they still could not read novel combinations of the same word elements in the criterion test. This gap had to be filled by including and permitting students to practice on novel combinations.

Second, "the irrelevancy hypothesis" led to eliminating items that were unrelated to the criterion test. They found that irrelevant items were distracting and that their elimination improved performance.

Third, "the mastery hypothesis" assumed that the student should not be permitted to move on to subsequent topics until he mastered the present one. When the child faltered, he was branched back and given more practice until he completely mastered the element.

The technique of successive empirical iteration of each segment until specified objectives are achieved is quite effective and quite different from the more conventional procedure of building a complete instruction package before evaluating it.

c. Lesson Design

Suppes and Atkinson of Stanford University have developed two approaches to CAI lesson module design - The Block Design and The Strand Design [94, 95]. The Stanford elementary school mathematics program is based upon 24 concept blocks or units for each grade level. A block is comprised of lessons for seven days' work, arranged sequentially. The student's first lesson in each block is a pretest, on the basis of which the computer assigns one of five lessons of varying difficulty. The student must obtain 80% or higher on each drill before he is permitted to proceed to the next level of difficulty. If a student receives a score of less than 60%, he is branched down to the next lower level of difficulty. If he is between 60% and 80%, he remains at the same level. The final day is reserved for a post-test. In addition to drill lessons, individual reviews selected from previous blocks are also presented. The drill lessons take from two to ten minutes to complete and students are expected to do at least one per day. The drills include both verbal and numerical exercises.

The concept blocks can be arranged to correspond to the sequence of topics in various textbooks. They can also be adjusted by grade level and for five levels of difficulty. The computer automatically matches presentations to student performance and provides reinforcement through immediate feedback to student response. Students may proceed through the materials as rapidly as they wish. These adjustments insure that poorer students as well as students of high ability can nave successful learning experiences.

The current reading curriculum program uses a strand design approach. The program is divided into six strands of basic component skills of initial reading: 1) letter identification, 2) sight-word vocabulary, 3) phonics, 4) spelling patterns, 5) comprehension and 6) language arts. A strand is defined as a series of problems of the same operational type arranged sequentially in classes according to their relative difficulty. A student proceeds through strands in a linear fashion and progresses to a new exercise within a strand only after he has met an individually specifiable performance criterion on the exercise.

Entry into each strand is dependent upon a student's performance in earlier strands; however, a student may work in several strands simultaneously. Once in a strand, however, his progress is independent of progress in other strands. Students spend two minutes in each strand and eight minutes total per day.

Cooperative Curriculum Efforts

Many of the currently available programs were designed for research purposes and documentation was limited or changed as different experimental treatments were introduced. Of those who designed instructional applications to be used in their classrooms, few had the time or resources to document the materials or to test their educational effectiveness. Consequently, since the quality of instructional programs is generally low and the documentation poor, there is a natural resistance to use instructional programs created by someone else. However, some cooperative efforts have been organized to overcome some of these obstacles.

The Illinois Institute of Technology (IIT) Regional Cooperative Network, with its nine participating colleges and universities, is cooperatively developing curricula in mathematics, biology, chemistry, physics, psychology, sociology, education, business management and economics [96]. Each campus selected four faculty members as group leaders to be actively involved in the design and implementation of course curriculum materials. The group leaders spent a summer surveying the uses of the computer in their disciplines and in developing applications.

Since the purpose of the IIT Network was to enhance cooperative development of college curriculum, a four-step plan was devised. First, specialized computer programming was introduced at each campus. Although most schools offered computer programming, the effective use of the network required that the users possess an understanding of the languages available through the network and how to use their remote terminal. Faculty members were selected from each campus to attend a summer seminar. On returning to their campus they assisted other faculty members in developing courses and seminars for both the faculty and the students. Assistance was also provided from IIT. Second, course development was begun. Six of the academic group leaders visited each campus to talk to faculty and then devised programs for course enrichment. During the first year they completed the adaptation of a statistical package, a business game and a number of programs written in BASIC. Third, curriculum development proceeded from the selective introduction of computing into a few courses the first year to the wide spread use throughout the curruculum in the second year. The fourth and final step was evaluation. The evaluation included interviews with faculty and students on each campus as well as by level.

One of the major obstacles to the widesperad use of curricula is the lack of documentation and procedures to facilitate the movement of materials from one location to another. Five regional computer networks, Dartmouth, North Carolina, Texas, Iowa and Oregon are cooperating in an experiment (CONDUIT) to evaluate alternative ways to transport instructional materials. They will seek to create the necessary procedures and documentation to permit instructional programs developed on one computer system to be efficiently transported within and among any of the various networks and to be effectively used in the classroom. Thus, a program written on one computer in the network will be readily available to 97 colleges with approximately 276,000 students. They will (1) catalog all programs in the network, (2) develop methods to evaluate the quality of the materials, (3) develop procedures for documentation, (4) develop accounting practices, (5) develop training methods, and (6) evaluate the use of materials in the classroom.

Cost-Effectiveness

There are numerous factors to be considered when evaluating the cost-effectiveness of computers in education [97]. In evaluating the costs of a system one should consider whether the equipment is to be purchased or leased. Are installation and maintenence costs included? Air conditioning may be required for the equipment and special classroom space may be needed for the terminals. Is staff training included? Similar systems may have widely different operating costs as a function of the sophistication of system personnel. Are curriculum costs included? Curriculum development costs in many cases may exceed the cost of hardware. Telecommunications costs are a major factor in any system that provides remote access to the computer. When comparing the computer with other media or teaching approaches, one should consider the life-cycle costs of the systems. Although initial costs of instructional computing may be high compared with other media, the total cost over time may be considerably less. The instructional use can also affect the cost. Does the computer application involve one student using a terminal in the tutorial mode or does it involve an entire class using the terminal for simulation or game playing? Is the computer to be justified on the basis of its ability to deliver low-cost instruction or is it to be justified on its value as scientific equipment such as a microscope, telescope or chemistry laboratory? All of these factors can influence the cost and effectiveness of computer systems.

Bunderson makes a distinction between mainline and adjunct uses of computing [98]. He defines mainline applications as those which teach new concepts and information in a highly effective manner and supplant teaching staff and facilities. Adjunct uses are those which may improve the quality of education but do not supplant staff or facilities. While mainline applications have the potential for reducing costs and improving performance, adjunct used can only increase the cost of education.

CAI Costs

Bunderson reports that the costs of quality CAI curriculum vary widely with some costing as high as $20,000 per hour of tutorial instruction [99]. At Texas, the development costs of an English punctuation CAI program were $4700 per instructional hour. Based upon their previous learning experiences, Bunderson says that today they can now develop a carefully designed, high-quality tutorial CAI program for $3,000 per instructional hour.

It is estimated that the costs of CAI today range between $3 to $10 per-student-hour. Kopstein and Seidel, in an analysis of the economics of CAI and Traditionally-Administered Instruction (TAI), estimate that the costs of instruction in the elementary and secondary schools to be about $0.60 per-student-hour, and $1.50 per-student-hour in higher education [100]. They conclude that while it may be assumed that CAI is as effective as traditional approaches, the cost per-student-contact-hour for CAI is higher by a factor of ten. These costs, they say, are too high to justify replacement of traditional methods except in some high-cost activities in higher education such as engineering or medicine.

Newly developed equipment systems do offer the potential for significant cost reductions and greater instructional flexibility. Bitzer estimates that the PLATO IV system, using newly developed technological devices, can provide services as low as $0.34 per-student-hour [101]. The MITRE Corporation estimates that their TICCIT System could reduce costs by an order of 10 to 1 over current CAI-CMI Systems [102].

CMI Costs

Duncan Hansen of Florida State University, using an operational 64-terminal system, concludes that the costs of CAI are approximately four times more costly per instructional hour than CMI [103]. The CAI cost per hour for development was $4.07 and the cost of operation was $1.79 per hour. The cost for CMI per hour for development was $1.04 and the cost of operation was $0.59 per hour.

Costs of Adjunct Instruction

The Pierce Commission in 1967 recommended in their study on computers in higher education that universities should spend an average of $60 per academic year per student for computing [104]. They note that in selective universities in the United States, the costs of library operation range from $50 to $200 per year per student, with the national average at approximately $48 per student. They also point out that for first-year chemistry students in courses with a laboratory, the average cost is $95 per year per chemistry student.

Dartmouth College is an example of an institution with high computer-use for instructional purposes [105]. The computer is a time-share GE-635 and has a computer library of over 500 programs. The computer is used for administrative as well as instructional purposes. Both the students and the faculty have free access to the computer, and casual use as well as instructional use is encouraged on a basis comparable to the use of the library. Over 85% of the student body use the computer at one time or another. Charges are not made to the user but instead are made on an annual basis to the college. The Dartmouth College Regional Consortium services ten other colleges and universities and can serve 113 users simultaneously through local teletype terminals and 52 terminals located throughout the network. Operation costs for Dartmouth are between two and four dollars per terminal hour. During the 1968 academic year the average per student costs at Dartmouth were $114. For the academic years 1968 and 1969, the costs for the consortium were $2.43 and $4.81 per terminal hour, respectively.

Effectiveness

In many cases, CAI has built on and extended the work done in programmed instruction, and the research on its effectiveness may be relevant to CAI. Between 1954 and 1964, over 190 reports of original research were completed on programmed instruction and it was found that programmed instruction is effective for college, high school, secondary, primary, pre-school, adult, professional, skilled labor, clerical employees, military, deaf, retarded and the imprisoned. Using programs, students were able to learn mathematics and science, foreign languages, spelling, electronics, computer science, psychology, statistics and many other subjects [106].

There are 1[illegible]0 studies on Individulaly Prescribed Instruction and it can be concluded that IPI students do as well as non-IPI students. This is even more inpressive if one considers that IPI tests are not normative but instead are performance based [107].

Dr. Patrick Suppes of Stanford University has made several evaluation studies of the effectiveness of their CAI programs [108]. In 1966, using mathematics drill-and-practice for grades 3 through 6, he found that the CAI groups when tested on standardized tests performed significantly better than the control group. The following year, students in grades 1 through 6 and a second group in the State of Mississippi were tested and similar results were obtained. Tests were also conducted on a college-level computer-based course in learning Russian. The computer-based students performed better on an examination than the conventional-classroom control group.

Suppes concludes that CAI students do as well as or better than students using traditional teaching methods. He finds that teachers through concentrated efforts can do as well with a good regime of drill-and-practice in fundamentals of arithmetic as the computer groups. However, computer practice programs bring a kind of quality control that is difficult to achieve in a large number of schools. He found that individualized drill-and-practice in elementary mathematics produced the most impressive results in school environments which were not educationally or economically affluent.

Duncan Hansen of The Florida State University found that, with three replications of his computer-based, multi-media CAI college physics course, performance was enhanced 20% over that of students in a conventional lecture course [109].

On the basis of three evaluative studies, Bunderson concludes that CAI permits students to achieve educational objectives in much less time and that saving in time of up to 40% is not uncommon [110]. Lower-ability students are able to achieve important gains often approaching the levels of higher-ability students. Although lower level students may take longer to achieve educational objectives, more succeed than using traditional methods. Failure is reduced. He notes increased motivation among many of the students. Based upon evaluation data on over 1,200 students completing a CAI mathematics course and another 100 in CAI English, he concludes that students at all levels of ability except the highest showed gains from pre- to post tests with deficient students making the highest gain. While attitudes toward the courses varied, most were favorably disposed.

In summary, the research and development of the 1960's, although severely limited by technology and pedagogy, demonstrated that students can learn by CAI at least as well as traditional methods but that the costs are too high for widespread use.

The National Science Foundation is providing support for a five-year effort to demonstrate the cost-effectiveness of these two uniquely different systems. It is hoped that the demonstration will be of sufficient scale and the applications broad enough that the results cannot be dismissed. The systems, techniques and components will be developed to the point that they can be marketed after the demonstration.

The MITRE Corporation will construct, test and install the TICCIT CAI System at each of two community colleges. Each system will have 128 student consoles, with curricula for a year's study in English and mathematics. The instructional materials will be prepared by instructional designers at the University of Texas and Brigham Young University. The materials will be developed with rigorous definition of objectives and educational strategies. It will be tested and "certified" to capture student interest and provide effective instruction. Student use of CAI will account for approximately 25% of the student's classroom contact hours. The TICCIT System will use an inexpensive mini-computer and all 128 student consoles will receive their pictures and instructional materials by a single television cable. Time-division multiplexing by frame will send the message from the computer to the terminal. The student console will consist of a commercial television receiver and keyboard which will receive, store and refresh locally. The system will also have sound.

The University of Illinois Computer-Based Educational Research Laboratory (CERL) will install CAI student consoles (PLATO IV) in a number of elementary, community college and university classrooms. Courses will be provided in reading and arithmetic at the elementary level, and mathematics, chemistry, physics and biology at the university level. The elementary-level materials will be developed at the University of Illinois Curriculum Laboratory and the college-level materials will be developed by the instructors themselves.

A large computer located at the University will serve all consoles simultaneously through a single educational TV channel. Initially, 400 to 500 terminals will be installed. Later, up to 200 terminals will be serviced. The student console includes a plasma panel, designed at the University, which has the capability of providing slide projection locally for static information, dynamic graphic information, and randomly accessed sound.

Evalution of the two systems by an independent group will include the cost-effectiveness of CAI and the advanced hardware, software and courseware. There will be pre- and post-testing of participating students and control groups using standardized tests as well as special tests to measure behavior and motivation. In addition to student performance, costs, system performance and operations will be analyzed and evaluated.

Costs of Administrative Systems

While administrative computer-based systems vary greatly, several examples may give some indication as to the costs of such systems [111]. The University of Utah, for example, with approximately 16,000 students, provides routine data processing, scheduling, management control, long-range planning and forecasting. They use an IBM 360/40 with a yearly rental of $150,000 to $200,000 and allocate a similar amount for staff costs, for a yearly annual cost of $300.000 to $400,000. The Ohio State University, with a student enrollment of 41,000 and a total operating revenue of 170 million dollars, estimates its data-processing costs at $1,130,000 plus $53,000 for personnel. The University of Illinois, with 50,000 students on three campuses, estimates equipment rental at $750,000 per year, and $1,150,000 direct costs for data processing.

In an analysis of problems and issues associated with administrative computer applications at 50 representative colleges and universities, it was concluded that no single model of wisdom was encountered and that there are as many patterns of development as colleges [112]. The size, wealth, growth rate and experience of the institution all have a bearing as well as does the relative importance of teaching and research. They conclude that careful planning, gradual development and replanning are all essential to the development of an effective viable system.

Dr. John Hamblen notes that there are over 200 computer systems with numerous models and configurations. They range on a monthly lease from a few hundred dollars to nearly a quarter of a million dollars and their purchase prices range from a few thousand to more than 10 million dollars [113]. He finds that there are a wide range of alternatives from time-sharing terminals, remote batch to mini-computers. He concludes that not only is there a computer system to fit every budget but there is one available for any mission in any type of organization.

Concluding Statement

The computer and mass education have and will continue to play a significant role in the improvement of the quality of life and in economic development. The instructional use of computers offers a hope for providing a quality education to ever-increasing quantities of students within the current generation.

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