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ABSTRACT

An overview is provided of the Fourth Revolution, i.e., the revolution which is taking place in education as a result of the introduction of computers into the field. The growth of computing in education, especially in higher education, is traced, and some major National Science Foundation (NSF) programs are mentioned. Following this, a few of the most significant computer-assisted instructional system which have been developed with NSF support are described and the problems associated with the production and transportability of courseware are surveyed. The extent of computer literacy, both in the United States and abroad, is reviewed and, a discussion of the major needs which exist with respect to the use of computers in education is presented. (PB)

ED 087417

THE COMPUTER AND THE FOURTH REVOLUTION

Dr. Andrew R. Molnar*

I. The Fourth Revolution.

The Carnegie Commission on Higher Education has recently published a report entitled the "Fourth Revolution" which takes its title from Eric Ashby's observation that four great revolutions have taken place in education.[1/]

The first revolution was the differentiation of adult roles so that the task of education for the young was shifted in part from parents to teachers and from the home to the school.

The second revolution was the adoption of the written word as a tool of education and with some reluctance writing was permitted to co-exist with the spoken word.

The third significant change was the invention of printing and the widespread availability of books.

And the fourth revolution is the development of electronics, notably radio, television and the computer. The computer, however, is the imperative in the fourth revolution.

II. The Growth of Computing in Education.

In a little over 15 years, academic computing has grown at a phenomenal rate such that in higher education:[2/]

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

This paper is based on comments made at the April 17, 1973 Annual Convention of The Association for Educational Data Systems in New Orleans, Louisiana.

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(1) Access to Computers.

All major universities and most colleges provide computing services to their students either through local facilities or access to off-campus facilities.

(2) Expenditures.

Expenditures in the last decade have increased over ten fold with 50 million dollars spent on computing in 1963 and an estimated 540 million dollars being spent in 1972.

(3) Type of Computing.

Of that amount spent, 30% was spent for instructional use; 32% for research use; 34% for administration and 4% for services to other institutions.

(4) Sources of Support.

This growth has occurred in spite of a diminishing percentage of contributions from Federal sources. Currently, 70% of expenditures for computing comes from institutional funds. In 1965, 36% of the funds came from Federal sources; in 1967, 23%; and only 17% in 1970.

(5) Computer Science Majors.

In the last five years the number of computer science degree majors have increased by a factor of 15 from approximately 5,000 to 75,000 students.

(6) Language Substitute.

Four hundred and seventy departments now permit the substitution of computer languages for foreign languages. This is a three fold increase in the last two years.

(7) Curricula.

Computer-based curricula has grown from less than 100 computer-based packages in 1965 to over 6,000 in 1972 -- an increase of a factor of 60 over a seven year period.

In secondary education while the figures are less complete, we do know that in 1970 34% of the Nation's secondary schools had access to a computer for administration and/or instructional purposes.[3/] In 1963, a survey estimated only one percent of our Nation's secondary schools used the computer for instructional purposes; in 1966, that increased to 1.7 percent and finally to 12.9 percent in 1970. This represents a growth in instructional uses of over 12 fold in little over seven years. This amazing exponential growth of academic computing has come about in spite of a growing financial problem faced by education.

III. National Science Foundation Programs.

Dr. H. Guyford Stever, Director of the National Science Foundation (NSF), says that the Foundation's programs provide for continued strong support for science with an effective balance between research and education programs.[4/] The highest priority, however, will be research programs. The NSF budget for Fiscal Year (FY) 1972 was 600.7 million dollars and the FY 1973 expenditures are estimated at 615 million dollars. The requested FY 1974 budget of 641.5 million dollars includes 58.9 million dollars of FY 1973 carryover funds.

The new restructured Science Education Improvement Programs provide support for programs that are designed to (1) increase science education effectiveness; (2) help provide the essential number and variety of trained scientists and engineers and; (3) make the general public more knowledgeable as to the potential uses of science and its limitations so that they can deal more effectively with problems requiring an understanding of science and technology. NSF Science Education Improvement activities in FY 1973 are estimated at a level of 47.0 million dollars versus the planned 80.8 million dollars and compared to a FY 1968 high of 125 million dollars. In FY 1972, the budget was 73.4 million dollars. The requested FY 1974 budget is for 60 million dollars.

(1) <u>The Office of Computing Activities</u>.

The Office of Computing Activities was established in July, 1967 to provide Federal leadership in exploring and developing computer technology and the uses of the computer. The Office administers a program in Computer Science and Engineering which supports basic research in Theoretical Computer Science, Software and Programming Systems and Computer System Design. Another program, Computer Applications in Research, seeks to support research studies which focus on the exploitation of advances in computer technology to further research in science. Support is being provided for exploratory studies to develop a National Network of computer-based resources in support of research and education. A new program, Computer Impact on Society, is concerned with studies of the impact of computers on organizations and individuals. The FY 1972 budget for OCA was 12.5 million dollars. In FY 1973, the Office will spend 10.0 million dollars and 10.0 million dollars is requested for FY 1974.

(2) Technological Innovation in Education.

The Computer Innovation in Education program has been transferred out of the Office of Computing Activities to the Education Directorate of the Foundation and renamed the Technological Innovation in Education Group. The objectives of this group are to explore and develop new innovative uses of the computer and related technologies in education. In FY 1972, 8.4 million dollars was spent for this activity and 6.0 million dollars is estimated for FY 1973. In FY 1974, 7.0 million dollars is requested for the expanded functions. I would like to briefly describe some of the activities currently being supported.

IV. Computer-Based Systems

We have supported the development of a wide variety of instructional systems. Oregon State University has developed an on-line, interactive, graphic system for classroom use in science. The system permits the instructor to dynamically control the graphics terminal with a joystick 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 to a class of 200 students. This classroom use of a sophisticated terminal significantly reduces the cost-per-student hour of instruction.[5/]

Project IMPRESS at Dartmouth College is a conversational, interactive package for the social sciences.[6/] It permits the student to have access to over 100 files of social science data on a variety of topics. Rather than hear a lecture, the student formulates hypotheses about current social problems and tests them using a variety of statistical packages using current social data. The system includes pedagogical routines that guide a novice through complex statistical programs in a conversational manner with minimal previous experience and permits undergraduates to perform learning activities which would not otherwise be introduced until later years. This approach is unlike CAI and yet different from traditional problem-solving. The potential for IMPRESS and more advanced systems to reduce costs and offer a new instructional format is very attractive.

Currently, Dr. Seymour Papert of MIT and Dr. Robert Davis at Syracuse University, now with PLATO, have demonstrated the use of LOGO, a computer language, to teach and assist fifth grade children to compute functions and solve calculus-like problems. This activity seeks to avoid the rigid sequential presentation of mathematical concepts and through the use of the computer and computer artifacts introduce higher order concepts at a much earlier age. With this system children have demonstrated their ability to write programs to draw simple figures, construct complex geometric designs, write a frame-by-frame movie, generate music, write computer generated poetry, solve motion problems in Physics and program the movements of a marionette.[7/]

NSF has developed a number of experimental models of computer networks for developing and sharing computer resources for instructional purposes. Some use batch processing, others are interactive. One network combines closed-circuit television with remote computing. One experiment involved a nationwide disciplinary network for Chemistry departments while still another uses a network of minicomputers for small colleges. In the past four years, some 30 regional computing networks were established involving 300 institutions of higher education and some secondary schools. The program has provided members with access to a large computer with a library of instructional and problem-solving programs as well as technical assistance and training. Today, approximately three quarters of the networks are self-sustaining and continue to operate after the termination of Federal funds. This highly successful experimental program is now being phased out.

The research and development of the 1960's, although severely limited by technology and pedagogy, demonstrated that students could learn using CAI at least as well as and in some cases better than by more traditional methods. However, the equipment lacked graphics and audio capability. Software systems were not flexible or easy to program and were much too costly -- probably by a factor of ten. In order to remedy this situation NSF sponsored the development and demonstration of two advanced systems; one following a centralized, utility approach and another following a modular or decentralized approach. The projects will take five years and ten million dollars of NSF support.

The University of Illinois PLATO IV (Programmed Logic for Automatic Teaching Operations) system is controlled by a Control Data Corporation 6000 series computer with up to 1,000 terminals connected to the computer through a single television channel.[8/] The terminal consists of a keyset and a plasma display for computer generated information. The plasma display panel consists of two sheets of glass separated by a thin layer of gas. Points on the display are fired by the computer to generate words, figures and drawings. Up to 256 colored pre-recorded microfiche slides can also be displayed on the screen as well as dynamic information superimposed over the static display. More than 4,000 random access audio messages of up to 21 minutes in length can be recorded and selectively presented under computer control.

A touch sensitive panel permits a child who is reading and doesn't recognize, for example, the word "elephant" to touch the word on the display panel and have a picture of an elephant appear and hear the word in his earphones. The system will provide courses in elementary and secondary school curricula as well as community college and university level courses.

One hundred and fifty terminals are up and operating at Urbana and 400-500 terminals will be installed from Urbana to Chicago by September of this year. The system was also demonstrated via satellite in Italy and Switzerland last summer and the Organization for Economic Co-operation and Development (OECD) now has a terminal in Paris.

The TICCIT (Time Shared Interactive Computer Controlled Information Television) system is operated by a Data General, solid state, minicomputer with 128 student terminals.[9/] The terminal consists of a keyboard, a small color television to display computer generated displays, video tape or slides and audio. The courseware will consist of two years of Mathematics and English and will be written to follow a prescribed set of design procedures. The intent is to design and validate procedures that will yield high quality courseware which will be useful to large numbers of students in standard courses throughout the country. The system will be installed and tested in 1974 at two community colleges -- Northern Virginia Community College and Maricopa Community College in Pheonix, Arizona.

The Education Testing Services of Princeton, New Jersey will evaluate and report their findings for both the PLATO and TICCIT projects.

The MITRE Corporation is currently demonstrating the feasibility of interactive, computer-controlled television systems for home use.[10/] They have coupled a cable television system with a computer to demonstrate the feasibility of using a standard television receiver for home computer driven displays for homes in the new town of Reston, Virginia. Cable television permits two-way conferencing. The home user communicates with the computer through a touch-tone telephone. Lessons are addressed directly to his television receiver and he may use his touch-tone phone for calculations or answering questions. The demonstration includes the home use of 27 lessons for fourth grade arithmetic drill practice. A simple computing language, Mr. Computer, is also available for writing student originated programs. Since cable television permits two-way conferencing, the teacher may work directly with students at home during the day or conduct adult education in the evening.

It is foreseen that 2,000 individual homes may be served for a nominal monthly fee. The home user will be able to shop remotely by television. He will be able to receive his mail automatically by dialing his post office box number. His salary will automatically be deposited in his bank account by his employer and he will be notified through his television set.

Upon his authorization, bills such as mortgage payments will automatically be transferred to his creditors. The computer controlled television will display this information and he may take a polaroid snapshot for a hard copy receipt. The system can provide fire and security monitoring. The user will be able to interact directly with his doctor and thereby reduce the number of office calls or home visits. He will also be able to make home movies using a small low-cost video camera and later play it back through his home receiver. Demonstrations of these services are currently being conducted at Reston, Virginia.

V. Courseware and Transportability.

Based upon a number of NSF initiated studies, it became clear that courseware was a critical problem. EDUCOM, using 35 experts in a Delphic seminar, concluded that the most critical factor inhibiting the use of instructional computing was not cost but the lack of good, readily available computer-based educational materials.[11/] This led us to initiate a more purposeful attack upon both the short-range and long-range solutions to courseware development and transportability problems.

First, we initiated a state-of-the-art study to determine what existed and how useful it is. Second, for the short run, we emphasized the development, documentation and testing of existing, but yet unpublished packages. Third, for the long run, we supported the development and analysis of experimental models for creating incentives and transportability in order to better understand the characteristics of this rapidly changing field. We have encouraged interdisciplinary conferences for diffusion of computer-based instruction through hands-on experience and face-to-face discussion, with curriculum developers. Finally, we continue to develop computer courseware for classroom use.

(1) Strategies for Curricular Development.

The Human Resources Research Organization (HumRRO) of Alexandria, Virginia is conducting a state-of-the-art survey identifying all computer-based curricula by discipline, level, language, machine, and instructional use.[12/] Compelling examples of computer-based instruction and associated costs of development have been identified. Surveys of publishers and vendors were made. Currently, alternative strategies, their associated costs and consequences are being evaluated. One recommendation HumRRO has made is the creation of a National clearinghouse for computer-based materials for higher education.

(2) Curriculum Development - Project COMPUTe.

Based upon our survey of publishers, it became apparent that they were uninterested in developing and publishing computer-based modules. Also, the most compelling materials used in classrooms were found to be undocumented and only locally available. Further, neither institutional incentives, such as release time, nor royalties were available to stimulate individuals to document, debug and test their programs. Through a grant with Dartmouth College a national search was made for exemplary materials in the environmental and related sciences. The authors were invited to Hanover for the summer and the College provided computer time, programming and editorial services. Standard formats were devised for student, teacher and computer program materials. Publishers are being contacted about publishing an edited series as a package. Through special arrangements, both the authors and Dartmouth may receive royalties. The project we hope will accelerate the number of quality packages available and could create a commercial model for curriculum development efforts which the College could pursue after the termination of the grant.

(3) Transportability Problem - CONDUIT.

One of the most serious obstacles that we face is the problem of transportability of programs. Programs that run at one location are rarely available on request and if available, seldom work elsewhere. One solution is a National Academic Network which permits the field to develop but also permits others to have access to the materials. Short of interconnection, however, standards must be adopted to make materials compatible for a variety of existing systems and machines.

CONDUIT is a consortium of five regional networks involving 100 colleges and universities with an enrollment of 300,000 students.[13/] It seeks low-cost solutions to the problem of transportability. Disciplinary committees have identified 100 packages in eight disciplinary areas. CONDUIT-Central in cooperation with the computer center director, and curriculum coordinator in each of the five networks have documented and certified the instructional packages, established procedures and costs for transporting the materials and created self-instructional video taped materials based upon workshop experiences and are moving the materials from center to center and ultimately into the classroom for use and evaluation. An independent organization, HumRRO, has devised numerous hypotheses concerning organizational structure, transportability, information needs, training and accounting procedures and will evaluate the entire system.

(4) Conferences.

The dissemination of information concerning computer-based curricula, is, at best, very difficult. From experience, one of the most successful mechanisms for rapid dissemination has been through annual multidisciplinary and disciplinary conferences at which users present and tryout on computer terminals a wide variety of materials. The annual Conference on Computers in the Undergraduate Curricula produces 60 to 80 published papers on computer applications in approximately 20 disciplines and attracts approximately 1,000 attendees. This year's conference will be held June 18-21 at Claremont Colleges, Pomona, California. Disciplinary conferences have been held in Physics, Chemistry, and the Humanities.

(5) Courseware.

The NSF Science Course Improvement Program is currently supporting a four year project on Computer-Based Education (C-BE) at the University of Texas which is aimed at evaluating the impact of a critical mass of computer-based education on a broad range of academic subjects. Courseware will be developed in approximately 16 interrelated academic disciplines. The Foundation is providing 1.3 million dollars and the University is providing a like amount to develop and use the courseware in the classroom.

VI. Computer Literacy.

Approximately 60% of the world's computers are used in the United States. The United States is the prime user and principal producer of computers and computer-related equipment. Exports of computers are approaching one billion dollars and with respect to balance of payments, the United States is the only net exporter of computers in the world. A recent National Bureau of Standards study found approximately 2,300 different applications of computing in business and industry. The computer is fast becoming a national basic industry.

While the printed text was important to civilization because it permitted man to extend his immediate memory and to accumulate his past experiences, its true impact on society was not realized until there was a literate populace.

So it is with computers. The computer in its short span of history has been one of the most significant amplifiers of man's productivity. However, the widespread use of this powerful tool may be limited by the lack of public understanding and the public's inability to see how the computer may benefit them and society.

A recent AFIPS-Time Magazine study, "National Survey of Public Attitudes Toward Computing," showed strong public anxiety toward the computer.[14/] Approximately one-third of the Nation's adults still believe that the computer is some kind of "thinking machine" and has the power to think for itself. More than half believe th. they are too dependent on the computer and that computers are changing their lives too rapidly. Fifteen percent believed that their lives are worse because of computers; this is twice the number who feel technology in general has made life worse.

Federal programs in science and technology aimed at making significant gains in productivity and the general well-being of the public must also be concerned with public understanding of these developments. An informed populace can better understand the strengths and limitations of new technological innovations such as computing. The degree of "computer literacy" among the general populace may be the limiting factor in rapid technological advances and with it, national productivity.

A recent report to the National Science Foundation by the Conference Board of Mathematical Sciences (CBMS), entitled "Computers in High School Education," has also strongly recommended the development of a "computer literacy" curriculum for secondary schools.[15/] They recommend specifically the preparation of a junior high school course in computer literacy;

materials for an introduction to computing; materials for a number of science courses; special programs for students with unusual aptitudes in computing; vocational education; teacher training and the creation of an information clearinghouse.

VII. What is to be done.

While the fourth revolution is gaining ground, the current financial crisis in education offers a challenge and a major opportunity to advance the educational use of computers to a new plateau and in the process increase the quality of instruction while significantly reducing the costs. However, much remains to be done.

What we need is a complete system and a total curricula. Anything less will be costly and ineffective. At many locations, educators are still working with cast-off business machines and providing rigid one-dimensional instruction. Through the persistence of a number of educational innovators, we are on the verge of a "first generation" computer-based system. When this is accomplished we will have a medium without a message. What is needed is a critical mass of quality materials -- a total curricula. Then and only then will we be able to demonstrate significant cost-benefits.

Marshal McLuhan argues that the electronic revolution is totally new and is changing the very natureof human perception and experience. In the age of television and computer, McLuhan says that we move into the world of pattern recognition and out of the world of mere data classification. We cannot merely convert old programmed texts into computer formats. We must retool cur curricula to take advantage of the new degrees of freedom the computer offers. This trend is already becoming evident in much of the new curricula.

We need a market mechanism to develop and distribute instructional material. Currently, publishers find the distribution of computer-based materials uninteresting. Equipment manufacturers, especially in the minicomputer field, find that the availability of computer-based materials is important in the sale of equipment systems and they have done a good job in providing simple programs and materials. However, equipment is the manufacturer's business -- not curricular development. Therefore, unless there are some major mergers between publishing houses and vendors, we are unlikely to see the commercial sector play a vital role in education. Education will have to create its own organizational mechanisms specifically designed to create, develop and disseminate curricular materials or face the prospect of becoming the world's largest and most expensive cottage industry.

We need a new organizational mechanism to handle the new technology. John Gardner once observed that most organizations have a structure that was designed to solve problems that no longer exist. We must go beyond current arrangements if we are to develop. There are still no incentives to write programs on courseware which upgrade the quality of education or reduce the cost-per-student hour of instruction. Writers seldom get royalties or promotions and seldom share in any cost savings which may accrue to the University. Instructors are better advised to write research papers in their discipline than to develop computer courseware. Educational institutions who are serious about cost-effectiveness will eventually have to devise institutional rewards and/or monetary incentives if they wish to reap the benefits of instructional technology.

While there is a revolution in technology, there is an even greater revolution taking place in education. Just because we are on the right track doesn't mean that we will not be run over by changing events. Obsolescence is becoming a major problem in our knowledge society. The average man in the work force can be expected to change jobs six or seven times in his lifetime. The half-life of professional man is only about ten years.

Paul Armer proposes the "Paul Principle" which he contrasts with the "Peter Principle" -- individuals tend to rise in organizations to their level of incompetence.[16/] The "Paul Principle" states that individuals often become incompetent over time because they become uneducated or obsolete. He says that higher education is not even remotely prepared to take on the continuing education as a major task. He suggests that universities of the future will operate somewhat like hospitals. They would admit students not just one or two times a year but continually. On arrival a diagnosis would be made of the deficiencies in the student's knowledge and the educational process of individualized instruction would be designed to fill the gaps. Modern technology is now capable of delivering instruction to an individual's home, place of employment or any other location. Education is no longer restricted to the classroom and must seek a new role in the knowledge society.

What is the Federal role in these developments? While there is no explicit Federal policy toward computing and while it is difficult to identify programs with computing in their title, there are many activities being initiated at the Federal level. The Federal programs tend to favor innovation and research and tend to look at technology as a whole rather than at computers in particular. Currently, programs tend to focus on increasing productivity, that is, improving quality while reducing costs. They seek to support projects which benefit many institutions and many disciplines. Programs of institutional support, equipment grants and support for the acquisition and upgrading of computers have been greatly reduced or completely eliminated. The acquisition and development of technology and systems will fall to the States and to the education institutions involved.

How will this affect the future of computing? My prediction is that the development of instructional computing will follow the Xerox model. That is, in spite of the fact that the initial dry process copying machine was more expensive than the wet processing machines, it was adopted because of its convenience and its ability to meet a compelling need. Similarly, computing is so compelling a tool that it cannot be stopped. How fast it will take to develop and how expensive the development will be are the only questions to be answered in the fourth revolution.

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