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AUTHOR Molnar, Andrew R.
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ABSTRACT

Described is the current state of computer science education in this country. The information explosion in science and the shift in our economy from the production of industrial goods to a greater emphasis on science and knowledge-based industries has created a discontinuity in the nature of jobs and our educational needs. Computers are not a major part of American education, but have become indispensible to the operation of science, business, and government. Many schools have introduced computers into their curriculum, but the paper stresses that these local efforts only partially satisfy the country's needs at costs that are prohibitive and unnecessary when viewed nationally. Other nations have begun the task of restructuring their systems to include computers. It is stated that there is a national need to foster computer literacy, or the next crisis in American education will be the computer literacy crisis. (MP)

The Next Great Crisis in American Education: Computer Literacy

Andrew R. Molnar
National Science Foundation*

The Current Crisis in American Education.

In the early 1960's, educators found that a large fraction of the persons who taught scientific subjects were inadequately prepared in subjects they taught and that there were gross inadequacies in the instructional materials available to teachers.(1) The launching of the Soviet earth satellite, Sputnik, brought a renewed interest in science and became the catalyst for a major curriculum reform movement. Unfortunately, the educational reform did not ameliorate or solve the major social problems of our times and the reform movement waned.

Current events have conspired to create a new educational crisis. The fundamental assumptions and social consensus about education which evolved after Sputnik are now under question. Like it or not, we as a nation are now engaged in the social process of renegotiating the form and substance that American education will take for the foreseeable future.

We still face many of the same problems of the past, but in a new context. A synthesis of three major studies of the needs and practices in our nation's schools supported by the Office of Program Integration of the National Science Foundation (NSF) concludes that,

*The views expressed are those of the author and do not necessarily represent the views of the National Science Foundation. This paper is based upon comments made at the February 16, 1978 meeting of Society for Applied Learning Technology in Orlando, Florida.

in large part, today's problems derive from declining enrollments, increasing costs, the relatively ineffective teacher support structure, and a back-to-basics movement.(2)

1. Declining Enrollments.

A recent study, The Condition of Education, reports that the elementary school population is expected to decline in size for the next five years; the secondary school population has now started to decrease; and the college age population is expected to increase slightly until 1980 and then decrease.(3)

2. Increasing Costs

In spite of the decreasing enrollments, per-student expenditures, total expenditures, and the percentage of Gross-National-Product (GNP) spent for education are expected to increase. The percentage of GNP spent on education (7.9%) now surpasses both the percentage for health (7.6%) and defense (5.5%), and the percentage spent on education has exceeded that spent on defense since 1973.(4)

3. Ineffective Teacher Support.

Since declining enrollments means less external funds, it follows that fewer new teachers are being hired and the average age of the faculty is increasing. In addition, 13% of science, 12% of social studies and 8% of mathematics teachers felt themselves inadequately trained to teach one or more courses assigned to them. The lack of funds has also led to fewer replacements of dated textbooks and equipment. Further, it is reported that over half of all science and social studies and two-thirds of all mathematics classes use a single textbook and many teachers use no supplementary aids other than the chalk board.(5)

In general, teachers tend to be less prepared and find it more and more difficult to keep abreast of the current developments in science and technology. They tend to be supported with one, often dated, textbook and little or no supplementary materials. This has led to a condition similar to that of the pre-Sputnik era.

4. Back-to-Basics Movement

After a decade of curriculum revision, a strong public reaction has occurred which seems to stem from a dissatisfaction with the innovations of the 1960's and the concern over declining national test scores. Half of the adults with children in school believe that schools should devote more attention to teaching basic skills.[6] This has led to a feeling that reading and computational arithmetic are the building blocks of education. While many still feel that science is important, they feel that reading, arithmetic, vocational skills and remedial courses are more important. As a consequence, about 50% of students take no science after grade ten.[7] In general, there is a trend toward the relaxation of science requirements in our nation's schools.

The trend away from science is occurring at all levels of education, from the inner city schools to the most prestigious universities. The science curriculum has been attacked as too diverse, too complex, and too difficult. There is a trend toward a more basic curriculum and more basic skills. The current movement has been characterized as a withdrawal from complexity and the acceptance of "minimalcy." Is this reactive policy adequate to cope with the changes occurring in our society? Are there other policies more suited to our times and conditions? What is the nature of the changes which are occurring in our society?

Our Changing Society.

Our economy is in a period of significant and fundamental change. The lack of low-cost energy sources and the diminishing supply of raw materials has led to a shift from the production of industrial goods and services to a greater emphasis on science and knowledge-based industries. An extensive study of the U. S. economy, concludes that for the year 1967, 46% of GNP was produced by information industries and that nearly half the labor force held information related jobs and earned 53% of the labor income.(8) Dr. Daniel Bell points out that the growth rate of professional and technical employment is twice that of the average. This group has increased from 3.9 million in 1940 to 13.2 million in 1975, thus making professional and technical persons the second largest of eight occupational divisions, exceeded only by semi-skilled workers.(9) Information has become a national commodity and a national resource and has altered the very nature of work. We as a nation have moved from being predominately an industrial society to being an information society.

The "information explosion" is probably felt most in the area of science. It is estimated that 100,000 scientific and technological periodicals are published each year throughout the world. In the United States, 80,000 technical reports are produced per year and this number is increasing at a rate of 14% per year. There are 2,000,000 scientific writings of all kinds produced per year or 6,000 to 7,000 articles per day.(10) This enormous growth in information has increased the diversity and complexity of science. Dr. Herbert Simon says that these developments have changed the meaning attached to the verb "to know". He says, in the past "to know" meant to have stored in one's memory, but today knowing now shifts from having actual possession of information to the process of having access to it.(11)

The United States over the past two decades, has been the major user and prime exporter of high technology. Today, statistical indicators show that the United States is fast being overtaken in innovation of new technology by more dynamic foreign economies.(12) Our technological lead in computing, which some feel offers the best solution for increased national productivity, is also waning. The U. S. Department of Commerce reports that British, French, West German and Japanese computer firms with strong government support will offer severe competition in the near future.(13)

A number of foreign governments are now working cooperatively with commercial firms and educational institutions in their countries to mount a challenge to our leadership. They are investing large sums of money into research and development of computer-based industries. More significantly, they have placed a high priority on the development of computer-based skills in their educational systems. The key to the success of this technological challenge lies in adopting new educational methods which make the computer an integral part of the educational process from kindergarten to the university and which permit people to experience computer uses and practices on a day-to-day basis.(14)

In summary, it is evident that problems of the economy, science, education and the computer are all interdependent and highly related. Science driven innovations spur the economy and create new jobs. Computers increase productivity but require a more skilled and professional labor pool with a broader education and a greater familiarity with the tools of science. And international competition for the lead in knowledge based industries is likely to increase in the near future.

The Power of the Computer.

The impact of computers on science has been revolutionary. Computers permit scientists to organize and access huge quantities of information. While operating at speeds of up to a picosecond (a trillionth of a second), computers shorten the time necessary for lengthy calculations and enable scientists to solve problems that were once considered beyond their capacity.

The computer provides science with a powerful tool for coping with the complexity of knowledge and the ever expanding information base. As a tool, the computer is no less important to education. However, the computer, which has become indispensible to the operation of science, business, and government, does not play a major role in American education.

1. Integrating the Computer into Education.

Computers and even hand calculators have made obsolete many subjects and have relegated the calculation of square root, logarithms and fractions in education to the level of importance of dipping candles and tanning hides. Just as automated information has ended jobs in industry, it has also ended subjects in education. One might ask, what happened to the slide rule? The world's largest producer of slide rules has discontinued their production. Within seven years after it was created and three years after it became widely available, the hand calculator has driven the slide rule out of education and has created a new threshold for problem-solving in science and mathematics courses. This development has occurred in most cases, without planning and in spite of educators.

Several commissions have studied the problem of integrating computers into education. The President's Science Advisory Committee concluded that if educational computing is to find a useful place in colleges, substantial revision of course material in the various disciplines is necessary. This recommendation was reiterated by the Commission on Instructional Technology, the Carnegie Commission on Higher Education, and the Conference Board of the Mathematical Sciences.[15]

2. The Computer as an Object of Science.

A meeting of school experts was convened by the National Science Foundation to consider the impact of the hand calculator on elementary school mathematics. A mathematician and author of many popular textbooks observed that the first six years of mathematics in our schools is devoted to learning the four basic functions of addition, subtraction, multiplication and division. He asked "if we introduce into the first grade, calculators which automatically perform these functions, what will the children do for six years?" Indeed what will children do?

Technology and knowledge are inextricably linked. If we look at the current curriculum we will find whole areas of knowledge built around technology such as the inclined plane and the pendulum. Dr. Seymour Papert of M.I.T. finds that young, elementary school children, given the availability of a computer, are capable of solving complex problems in physics, geometry and physiology. They are capable of writing computer-based poetry and music. (16)

The computer, Dr. Papert uses, drives a device called a "Turtle" which has audio and light sensitive receptors (ears and eyes). He uses this device to help teach "Turtle Geometry"--a mathematics embedded in the world of an electro-mechanical turtle. He teaches physiology with a computer-driven "worm"; music composition with a computer-driven music box; and English with computer-generated poetry.

The significance of Dr. Papert's work is that it demonstrates that today's curriculum greatly underestimates the capacity of children to deal with complexity and arbitrarily postpones the introduction of problem-solving skills to a point so late in the curriculum that most children lose interest or become so dependent on guidance that they never master these skills. Computing provides a new way of thinking and as such should be introduced as early as possible. The power of the computer eliminates many manual skills that are prerequisite to mastery and provides a powerful, general problem solving tool that permits students to cope with problems of complexity.

The Social Costs of Illiteracy

Many schools and colleges have initiated programs to integrate the computer into the classroom. Dartmouth College has been a leader in integrating the computer into the academic curriculum. Dr. John Kemeny, President of Dartmouth College and researcher on the atomic bomb, says "it took twenty of us twenty hours a day, six days a week for an entire year to accomplish what one Dartmouth student can do in one afternoon." (17)

At Dartmouth, the computer is considered as important to the student as the library and as such students are permitted to use the computer, free-of-charge, any time of the day, for any reason. I am told that while other universities have difficulty in attracting students, Dartmouth accepts one of eight applicants. A recent survey of applicants to Dartmouth found that the most frequently cited reason for wishing to attend was Dartmouth's reputation for instructional computing.

Dr. Donald Michael writes in The Unprepared Society that there is a growing separation produced by those working creatively with computers and the rest of the population. He says that "ignorance of computers will render people as functionally illiterate as ignorance of reading, writing, and arithmetic." (18) It is clear that if we are to have equity in our educational system, all students must have access to computing and must become literate.

Some argue that computer literacy is the responsibility of the individual and can be learned after one leaves school. However, there is a psychological cost involved in reclassifying and relearning concepts once learned. This especially is true when the new concepts make previous models obsolete. Imagine the engineer who graduates with honors but has not been exposed to computers and must compete for a job in industry, now permeated with computers. Imagine the drill-press operator who graduates from a vocational school only to discover that machinists in modern factories don't use machines but instead program computers to run machines. A student who graduates without being exposed to computers has had an incomplete education. To retrain after graduation creates an unnecessary human waste and incurs a high, unacceptable social and psychological cost.

Who is Responsible for Computer Literacy Programs?

Some argue that the private sector who will benefit most from the sale of computers should support the development of computer literacy. Dr. Arthur Luehrmann of the Lawrence Hall of Science says that publishers do not teach reading because people may go out and buy their competitors' product. Therefore, computer vendors or publishers cannot be reasonably expected to provide such services.(19) Consequently, the burden of computer literacy must fall to the educators.

But, why is computer literacy also a national problem and not just a local problem? Several studies have concluded that the lack of good computer-based educational materials is the major obstacle to the widespread use of computers and that this need is only partially being satisfied by local efforts but at costs which are prohibitive and unnecessary when viewed from a national perspective.(20)

The Federal Government is the largest single user of computers in the United States. The Government has 10,000 computers and spends approximately ten billion dollars a year on equipment and personnel. Computers have become indispensable to the operation of government. However, Federal agencies which use computers to make significant gains in productivity and to improve the general well-being of the public must also be concerned with public understanding and acceptance of these systems. An uniformed and uneducated citizenry may limit or reject technological advances.

We tend to underestimate the degree to which the technological literacy pervades our society until we try to introduce technology into other cultures. Attempts to introduce computers into some, less-developed, nations have not succeeded because of the lack of a significant number of computer literates. Energy-rich nations have developed national programs to exploit their resources; so we must develop our human resources. In an information society, a computer literate populace is as important as energy and raw materials are to an industrial society.

It has been recognized that considerably more than half of the increase in American productivity has been due to scientific and engineering advances. Many economists feel that the major capital stock of an advanced nation is not its physical equipment, but the body of knowledge amassed from science and the capacity to train its people to use knowledge effectively. (21)

In a democratic society, it is not only a right but an obligation for all citizens to participate in the action of their government.

Some feel that due to the high cost of equipment and training only big government and big business will benefit from the use of computers. Others feel the advent of small personal computers will solve this problem. They argue that information networks and services will make it possible for the public to benefit from the information without having to learn a computer language. However, in either case, citizens without any idea of what computers can do will be no better off.[22] Computer literacy is a prerequisite to effective participation in an information society and as much a social obligation as reading literacy.

Education in a Complex Society.

Our society is growing more and more complex. The information explosion has created a discontinuity in the nature of our educational needs. Science curricula designed to meet these needs have been criticized as being too difficult and too complex for most students. Many feel that we should reduce the amount of science taught and instead teach more basic skills. However, the computer is ideal for dealing with complexity, and difficulty is not inherent in the subject matter but in our ability to cope with it. The computer provides us with a problem-solving tool capable of overcoming these difficulties.

Will computers reduce the high cost of education? It is unlikely, in the short run, that computers will reduce the costs of instruction. On the other hand, will proficiency in simple computational arithmetic prepare students for an information society? Some say we did not invent automobiles by breeding better and better horses. Just as the internal combustion engine revolutionized transportation, so will the computer alter education. After all, how cost-effective is it to efficiently teach skills that are obsolete, for jobs that no longer exist, in a society that demands knowledge about computers. Instead, we must ask what is basic in a predominately information society?

We should take a long view of the question of cost. It is estimated that 15% of the major ideas in regard to computing have originated at universities. In addition, some feel that the federally supported university research in the field of semi-conductors was the basis for the electronics revolution and led to our international domination of the computer and aerospace industries.[23] It has been said that the single biggest impediment to the further growth of the multibillion dollar microelectronic industry is the fact that the vast majority of Americans are uneducated in the use of the computer.[24] In short, the academic community has created innovations whose contributions to our GNP are at least as large as the national cost of education. Further, a computer literate populace will facilitate the creation of new markets.

A study of innovation found that much of the knowledge used in developing innovations was based upon the knowledge received during the innovator's formal education. The study concluded that in spite of the fact that results of research are published in journals which are widely available, scientific knowledge does not become a relatively freely available good until it becomes part of the educational curriculum.[25] How do we introduce new innovations into education? Education is textbook bound and today's books make little or no reference to computer-based advances. A national effort is needed to introduce computing into the educational curricula and into our nation's textbooks.

Some countries with centralized educational systems have already begun systematic efforts to achieve computer literacy. In the United States where the responsibility for education is shared at the local, state and federal levels only collective action can bring about the needed change. Education today is in an intellectual crisis; we are following a reactive policy and are trying to solve new problems with old remedies. Other nations are beginning the task of adapting to a changing world. If we do not begin soon, the next great crisis in American education will be the computer literacy crisis.

There is a story of the commuter who ran to catch his train and on arriving late, commented, "if I had ran faster, I would have made it." A bystander said, "no, if you had started sooner you have made it."

In conclusion, there is a national need to foster computer literacy. Further, if we are to meet this need, we must ensure that high school graduates have an understanding of the uses and applications of the computer in society and its affect upon their everyday lives. We must permit students to use the computer as it would typically be used in business, science, and government. We must increase the quality of education through the introduction of computer-related curricula in a wide variety of academic subjects at all levels of education. A nation concerned with its social needs and economic growth cannot be indifferent to the problems of literacy. If we are to reap the benefits of science driven industries, we must develop a computer literate society.

FOOTNOTES

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