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ED039765

# A SUGGESTED TEN-YEAR PHASED PROGRAM FOR DEVELOPING, EVALUATING AND IMPLEMENTING INSTRUCTIONAL TECHNOLOGIES*

by James G. Miller**

Almost daily we hear of new instructional media, or novel, interesting, and versatile gadgets which can contribute to education. Their sophistication is rapidly increasing. The interest of educators is not in hardware and software for themselves alone, however fascinating they may be. Rather they are concerned as to whether these technologies can be used to achieve greater excellence of education from nursery school throughout life; to individualize that education and fit it to the needs of specific human beings; to share resources and scarce personnel in educational systems at all levels; and to cut costs in various scarce forms of matter-energy and information, including money for capital construction and operating funds, and the time of students, teachers, administrators, and staff members.

A national program to accomplish these purposes should be developed over the next decade by cooperative planning among schools, colleges, and universities, industrial organizations, and the government. Because they have the largest number of students, the <u>schools</u> should be the greatest users and constitute important proving grounds for the new

*This paper is based on four previous papers on general systems theory and its applications to educational processes: (1) Miller, J. G., <u>The Nature of Living Systems</u>, November, 1968; (2) Miller, J. G., <u>The Living Systems Involved in the Educational Process</u>, February, 1969; (3) Miller, J. G. and Rath, G. J., <u>Priority Determination and Resource Allocation by Planning-Programming-Budgeting and Cost-Effectiveness Analysis in Educational Systems</u>, March, 1969; (4) Miller, J. G., <u>Deciding Whether and How to Use Educational Technology in the Light of Cost-Effectiveness Evaluation</u>, April, 1969.

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media. The colleges and universities in their traditional research and development role should take the lead in the basic investigations underlying these new technologies, in their engineering development, and in trying them out in their own processes. Universities may also serve to protect the content information of the media from distortion by the profit motive or governmental control. The role of industry is to create hardware and software and operate communications systems. Government is likely to have four roles: (a) funding necessary basic and applied research and development; (b) subsidizing early operations, by such means as creating special rates for educational communications; (c) providing tax funds to support public education; and (d) regulating the technologies, as the Federal Communication Commission does of other sorts of communications, or as the Copyright Office does of uses of content materials.

## Organizational Considerations

Five to ten major university centers for research and development on instructional technology scattered around the United States, each with long-term block grant institutional funding by the government in addition to other projects grants, would in all likelihood be the best basis for national initiative in this field. Multiple university centers are probably better than a single governmental institute comparable to one of the National Institutes of Health, for the following reasons: First of all, such institutes usually cannot pay salaries to compete with the best academic centers, and they are restricted by the creeping bureaucracy endemic to all government agencies. To some extent, also, freedom of thinking in governmental institutes is constrained by political views of the public officials in power. Furthermore, the present pattern of the National Institutes of Health is to consume specialists rather than to produce them. There is a great shortage in the country of personnel trained in depth in educational technologies, and consequently all centers should educate students to work in this field at the same time as they carry out research, development, and operational functions. One National Institute of Educational Technology might be valuable, but it should certainly not be the sole center of its sort in the country or even constitute a major part of the total national effort in this area. Its own intramural activities should be quite separate from its extramural grant-giving functions if it is established. Several centers should be set up for at least two reasons: first, so that there will be no centralization of control of such a vital national function so vulnerable to ideological infiltration and subversion, and second, the existence of only one such center might develop parochial views and extend this narrowness nationwide. At this stage of development of educational technologies our country will profit from pluralistic approaches under various sorts of control. These activities might intercommunicate through a voluntary consortium of colleges, universities, and other related institutions of higher education such as the Interuniversity Communications Council (EDUCOM). Given the traditions of our country such a private organization of nonprofit educational institutions can probably be more effective than any governmental or industrial organization.

Research and Development Activities

All the centers that are set up should carry out basic research on systems theory, concerned with hierarchies of living systems and the relations between living and nonliving systems. Their research should deal with both their matter-energy processing subsystems and their information processing subsystems. Emphasis should be put on such promising and important fields as learning theory, communication theory, information theory, queuing theory, game theory, decision theory, and automata theory. A major area of research, particularly by social psychologists and sociologists, should be social resistance to the change produced by introduction of new technologies in educational systems. The centers' staffs should be interdisciplinary, involving mathematics, physical, biological, and social sciences, as well as engineering, and some of the humanities. They should be funded throughout the entire decade of the ten-year plan and indefinitely into the future. Over a decade the annual budget of the average center might increase gradually from $500,000 to $3,500,000.

Applied research and development should be carried out by all these centers and funded throughout the ten-year period with increasingly large grants. Emphasis should be placed upon the thorough development and field testing of specific techniques and content materials. Many workers in educational research have demonstrated in theory, or with relatively insignificant examples, that certain kinds of hardware and software can be useful in education. But careful development of instruments which have been systematically tested and are ready to use is rare. Complete segments of courses, full courses, and other sets of learning materials are urgently needed for instruction at all levels of elementary, secondary, higher, and continuing education. These should be carefully evaluated with groups in terms of their educational effectiveness and costs.

In addition a national program of federal government project grants for research and development activities should be established. Foundation and other private grants will undoubtedly supplement these.

## Hardware Needs

Throughout the ten years of the program intensive research should be carried out to improve the hardware of present instructional media and to add to those now available. The initiative for such activities should come from educators and those involved in instructional research, rather than from engineers. The educators should determine the need and state the specifications. They can then turn to engineers on university faculties or to industrial engineers in order to produce the product as required. Each one must be carefully and well engineered and field tested with cost-effectiveness evaluation, in the same hard-headed way that a new airplane, automobile, or electric toaster is evaluated by industry.

Funds should be available, especially in the first five years of the ten-year period, for the development of a number of specific types of hardware like those listed below. The ones which prove out should be ready for industrial manufacture on a mass basis by the end of the fifth year.

Among the major types of instructional hardware which currently appear to be in need of development are the following:

1. Computers especially designed for educational needs. In recent years no computer has been constructed for educational uses primarily, except perhaps the Illiac IV, a pattern-recognition computer designed and built at the University of Illinois at Urbana, and the IBM 1500, industrially designed for computer-aided instruction. Educators should have a role in stating the specifications for computers needed for educational computer-aided on-line time-sharing systems.

2. Inexpensive automated carrel to sell for less than $1000 when mass produced. Such a carrel should include audio input, visual input on a screen which can show black and white and colored letters, figures, still graphic materials, and moving pictures; an electric typewriter which can be operated on-line to a computer; and a light pencil whose beam can be sensed by an on-line computer whenever it is pointed at any part of the screen.

3. Portable microform reader. Utilization of microform has been widely restricted because microform readers are large and

bulky and because they rapidly tire the eyes of the user. As a result, libraries purchase expensive books rather than cheaper microform copies of the same materials which are available, because of user resistance to microform. This resistance could probably be significantly diminished if a portable microform reader were developed that could be carried in a small briefcase, perhaps even pocket-size. This reader should be capable of enlarging to full size microcards with black letters on a white background, white letters on a black background, and colored materials, and with adequate illumination so that the user's eyes do not tire. It is possible to reduce ordinary book pages clearly 40- or 45-to-1, so that they fit on a single microcard. If such a reader were available, many books could be carried around in a single briefcase. Research and development are now underway on a small, portable microform reader.

4. Automated carrel in briefcase. An entire automated carrel in an attaché case is probably attainable within the next ten years if an effort to develop it is given priority and support. It could contain a television screen, light pencil, micro-optical information storage file, remote television camera and tripod, teletype keyboard, touchtone keyboard for communicating with the local storage or a remote computer, and telephone. It would be powered either from a power outlet or from a rechargeable, long-life battery. The user would set up the TV camera in its tripod to photograph himself. Then he could transmit his own image to a receiver anywhere on a network over phone-vision line outlets to which he would connect his

briefcase. Over the same lines he could receive over a network from any location the image of someone he was talking to or data from a computer. What was not stored in the information file of the briefcase could be obtained over telephone or phone-vision lines of the network from a remote computer. In this way the user could get access to television lectures, documents, data, or computerized programmed instruction. The user could interact with a remote computer by light pencil, by telephone, teletype keyboard or touchtone keyboard.

5. Optical print reader. A machine is needed which can scan and rapidly read into digital storage entire books printed in ordinary type of many different fonts. Photoreaders exist at present which can read at the rate of a page a second, material typed in a number of fonts of typewriter type, but none yet can read, with adequate accuracy, many fonts of book type. Until such a machine exists, it will not be financially feasible to store massive amounts of textual material digitally in electronic memories which can then be searched for information that can be transmitted rapidly over electronic networks. If this development should occur, with mass memory storage hardware available now and soon to be improved, the operation of libraries could be greatly improved. For approximately the amount of federal money appropriated annually for libraries in the United States it would be possible to store the entire text of the Library of Congress, if the attendant complex legal copyright problems could be resolved. Thereafter schools, colleges, and universities could have access over networks almost on an instantaneous basis to the entire store of the Library of Congress. This would

remedy the great shortage of information of this sort that exists in many parts of our country today and create a true nationwide democracy of access to such information.

6. On-line electronic blackboard. If in group discussion rooms and classrooms it were possible at will to retrieve printed and graphic materials in black and white and color and to magnify them up on large surfaces--on-line to a computer like electronic blackboards--many aspects of classroom teaching could be facilitated. Large displays something like this are presently in use in command-and-control rooms of American military installations, but they are probably far too expensive for educational use. A cheaper form is required for mass production.

7. Home cartridge video-tape player and recorder. Audio-tape cartridge players already are in wide use. It is reliably reported that in the near future, color television sets will be equipped to play and record video cartridges. This coming development can be of great value for home study by students in schools, colleges, and universities, as well as by adults. Home television sets will become potential educational centers and can be used, therefore, both for recreational amusement and for education.

8. Educational satellite. Communications utilizing satellites are already in operation around the world. Satellites dedicated to educational communications are now feasible and are likely to be available by 1972. This broad-band facility will make possible transmission of all of the media that can be carried over networks, not only across

the United States but around the world.

9. Signal transmission by laser. Laser beams are capable of very broad-band transmission. This means that very large amounts of information can be transmitted rapidly and inexpensively. This information could be both printed or graphic, still or moving, visual and/or moving, relating to all the electronic instruction media.

Other sorts of hardware will also undoubtedly be found desirable as educational research and development expand.

## Software Needs

The experts agree that to create sophisticated and effective software is much more complex and difficult than to produce hardware. Many fundamental principles of software construction are understood, although improvements can constantly be made. The art of software development is young. There are basically two sorts of software: (a) systems software for operating the various types of computerized equipment in flexible ways which will be most useful for the educational process and (b) the programs of actual content material.

Throughout the ten years the phases of software development should be as follows: Basic research on software technology, including new methods of programming; creation of new programming languages; and work on basic linguistics in order to improve the ability of computers to translate text from one language to another or to search text and answer questions based on such searches.

In the first three years of the ten-year program, major content materials should be programmed in the different media for grade school, high school, and junior college curricula, and most popular college and university courses. By the end of three years, complete curricular materials in all these areas should be available, preferably from multiple courses and authors, to get different points of view. Between the third and the fifth year of the ten-year program, such content materials should be expanded to most or all curricular fields. Thereafter there should be more and more varieties and duplications of these various forms of content material. It is essential that there be multiple versions of such materials and that any author who wishes should be encouraged to prepare educational materials to go on the network. Quality of the content can be best assured by such competition.

Efforts should be made through basic research and development to study man-machine symbiosis. We should allocate to machines rote teaching and other activities that can be best done by individualized instruction with machines. Human beings, teachers working in small groups and individually with students should carry out the functions which machines cannot do now and very likely never will be able to. The emphasis in production of educational materials for these new instructional technologies should be not on learning facts but on learning how to find and use facts; or developing wisdom and judgment and on discovering how to live a full and fruitful life.

Legal Activities

During the first two years of the ten-year period, legal task forces made up of educators, lawyers, engineers, librarians, computer experts, television broadcasters, and other specialists should devote themselves to improving the present laws and regulations and spelling out ethical codes for the most effective operation of the instructional media. The Federal Communications Commission should establish rates and regulations that make possible the operation of all the media at local sites and also over networks. Furthermore, serious consideration should be given to special educational rates. One form of federal subsidy for education may be cutting the long distance communication rates for educational purposes below those for other purposes. In the development of new industries throughout American history, such federal subsidy has been common. It is certainly appropriate to subsidize the newly developing educational industry, most or all of which is and always will be nonprofit and which, in addition, is utterly vital to the country.

Present copyright legislation must also be rewritten to take into account recent developments in the new media and to provide appropriate reimbursement through royalties and licensing arrangements to authors and publishers while at the same time guaranteeing that all information useful to education will be freely made available. Copyright holders should not have the right to prevent their materials from being used on educational networks and other educational media. But they should have the right to receive appropriate reimbursement for the use of their copyrighted materials.

Laws and regulations governing educational network operations should be established to deal with anti-trust considerations, potential negligence, censorship, and so forth. In addition, ethical codes and laws concerning privacy of information and procedures for guaranteeing it where appropriate should be worked out. This legal activity should be followed up intensively during the first two or three years of the ten-year period. At the end of three years, well worked-out codes of laws, regulations, procedures, and ethics for the use of educational technologies should be available.

## Networks

In the first five years of the ten-year period pilot networks should be established, beginning perhaps with a single medium, like the Educational Information Network (EIN) dedicated to computers or like various educational television networks now in operation. These should be expanded to include all the instructional media which can be transmitted on networks, as planned for EDUNET.* Preferably operated by a university consortium and supported by the federal government, these pilot efforts should develop principles of operation, organizational structures and manning tables, rules for hardware and software compatibility, and methods of accounting and financing. Then they should obtain content materials and begin pilot opc tions. After evaluating their experiences, they should expand services which appear useful to all colleges and universities, schools, and other agencies in the

* Cf. Brown, G. W., Miller, J.G., and Keenan, T.A. EDUNET. Report of the Summer Study on Information Networks Conducted by the Interuniversity Communications Council (EDUCOM). New York: John Wiley, 1967.

society which can use them. By the end of the fifth year, these developments should be sufficiently advanced to begin to constitute significant factors in American education. Later they can be extended to other countries.

## Evaluation

No educational process should be accepted for wide use without appropriate evaluation on a controlled basis in comparison with other possible ways to accomplish the same ends. Throughout the ten-year period there should be basic research on effectiveness measurement and cost-effectiveness evaluation procedures. Beginning with the second or third year of the ten-year period when significant amounts of software are becoming available, these should be subjected to controlled evaluations of their costs and benefits or effectiveness. Comparative evaluations of competing materials should be made public by an agency sufficiently judicial not to be influenced by pressures from hardware or software development organizations, government, or any other source. This might be a quasijudicial governmental agency, perhaps associated with a National Institute of Educational Technology, but perhaps independent.

## Demonstration Centers

Because of the widespread resistances to change which have been mentioned above, few on-going educational systems are likely to make the radical changes in their structures and processes necessary to adapt themselves most effectively to the new technologies. Therefore it is recommended that, beginning with the third year of the ten-year program and extending through the eighth year (as soon as a reasonable mass of software content material is available for educational systems at any level), a number of federally supported demonstration centers be established. These centers would operate school, college, or university programs using the instructional technologies as much as possible and comparing them with traditional forms of instruction. These centers would run the gamut from nursery school to continuing education, including special types of schools, as for the mentally retarded or for prisoners. The learning environment in them would include every automated aid but would by no means eliminate human teachers whose roles would be to deal with the motivations of the individual students, to adapt the materials to their specific interests and personalities, and to instruct in those matters which have not yet been automated.

## Training in Educational Technology, Systems and Communications Science

There is a great shortage of persons concerned with the educational process who also have the background required to apply present knowledge in communication science and systems science to the use of the new instructional technologies. Therefore, colleges and universities should have bachelor's, master's, and doctor's programs in these fields. At the bachelor's level, educational technologists would be trained to be operators of the media. At the master's level supervisors would be trained with knowledge in depth of such matters as systems analysis, computer programming, computer-aided instruction course programming, and television script writing. Doctoral level training would be provided for those who are able to innovate and do research development in the new media and in systems and communication science. Those studying to teach in elementary, secondary, and higher education should be trained to use the media. In other professions, like medicine and engineering, it is universal practice for a student to get to understand the tools of his trade before he begins his professional life. It is strange that this is not generally true in education--particularly higher education. Educational administrators also should be trained in the media and in techniques for eliciting innovation from their teachers and professors, and for clearly indicating the administrations support for such innovation.

## International Implications

Once the hardware and software have been developed and tested out in the United States, they can be mass produced at reduced costs for use throughout the world. Electronic instruments can be provided with their own power sources, if necessary, and taken anywhere in the world. They can be interconnected with the United States through international educational satellites and by other means. The content materials can be translated into other languages. If such materials are to be most usefully employed in foreign lands, developing as well as to established nations, they must in each place be articulated with the local scene. American provincialisms must be eliminated from them. Emphases should be changed to suit the language, culture, and traditions of each country. In addition, every effort should be made to render instruction and examination materials culture-fair, not biased for or against any given country. At the same time one would hope that large parts of the curriculum would be of general international interest. International education using these common materials could be a major force toward peace. In some countries adequate preparation for higher education is not available and, therefore, in such nations remedial education courses appropriate to the country would be essential.

It is unlikely that automated instruction would be entirely self-sufficient for providing a complete education anywhere. Human instructors almost always must be involved to deal with problems of the student's motivation to learn, to tailor instruction to the personality of the student, and--along with fellow students--to provide social facilitation to the learning process.

## Funding

A rough suggestion about funding of a ten-year program by the federal government is indicated in Table 1. Of course, there would be other sources of funds in this country besides the federal

| Purpose | 1st Year | 2nd Year | 3rd Year | 4th Year | 5th Year | 6th Year | 7th Year | 8th Year | 9th Year | 10th Year |
|---|---|---|---|---|---|---|---|---|---|---|
| Block grants to Research & Development Centers | 2,500 | 5,000 | 7,500 | 10,000 | 13,000 | 16,500 | 20,500 | 25,000 | 30,000 | 36,000 |
| National Institute of Educational Technology | | | | | | | | | | |
| Intramural Program | 500 | 1,000 | 1,500 | 2,000 | 2,500 | 3,000 | 3,500 | 4,000 | 4,500 | 5,000 |
| Project Grant Program | 2,500 | 4,000 | 5,000 | 6,000 | 7,000 | 8,000 | 9,000 | 10,000 | 10,000 | 10,000 |
| Hardware Development | 5,000 | 15,000 | 25,000 | 25,000 | 25,000 | 15,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| Software Development | | | | | | | | | | |
| Basic research | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 5,500 | 6,000 | 6,500 | 7,000 | 7,500 |
| Content material preparation | 2,000 | 5,000 | 10,000 | 15,000 | 20,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| Subsidy to permit special rates for educational communications | 1,000 | 2,000 | 3,000 | 5,000 | 8,000 | 11,000 | 15,000 | 17,000 | 19,000 | 21,000 |
| Legal activities | 100 | 200 | 200 | 150 | 100 | 50 | 50 | 50 | 50 | 50 |
| Educational multimedium networks | 500 | 1,000 | 3,000 | 5,000 | 8,000 | 10,000 | 12,000 | 14,000 | 16,000 | 18,000 |
| Evaluation | 5,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Demonstration centers | | | 6,000 | 12,000 | 16,000 | 20,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| Training | 1,000 | 3,000 | 5,000 | 7,000 | 9,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| International programs | 500 | 1,000 | 1,500 | 2,500 | 5,000 | 7,500 | 10,000 | 15,000 | 20,000 | 25,000 |
| Totals | 21,600 | 40,200 | 71,700 | 94,650 | 119,600 | 132,550 | 147,050 | 162,550 | 177,550 | 193,550 |

Table 1. Funds Needed for a Ten-Year Phased National Program for the Development and Use of Instructional Technologies
(Amounts in thousands of dollars)

government, including private foundations, school systems, colleges, universities, and industry. What is proposed here is a massive national effort over a decade, and the costs must be borne by many agencies. In addition, of course, international financing by foreign governments and international bodies, as well as the United States Government, are important if the entire world is to benefit from the instructional technologies.