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ABSTRACT

Many new resources are available in education today. The author offers an evaluation of these resources, including their cost effectiveness. He discusses the resistance to change which has slowed acceptance of new forms of educational technology. He presents a table listing the major media of educational technology available today, together with a brief description of the strengths, weaknesses, and costs of each. Using the information listed in the table, he demonstrates the factors which must be considered in choosing an instructional aid. He evaluates in depth instructional television and computer assisted instruction. Using a series of fictional examples, he suggests an approach to decision making on new instructional media in educational systems at various levels--school, school system, college, university, state system of higher education, national educational system, and international education. A reference list is provided. (JY)

DECIDING WHETHER AND HOW TO USE EDUCATIONAL TECHNOLOGY IN THE LIGHT OF COST-EFFECTIVENESS EVALUATION

by James G. Miller*

What do we mean by "educational technology"? Sometimes this phrase may refer to any form of learning situation planfully established by an educational system, including a tutorial session, a group conference, a school class, or a large university lecture, as well as a wide range man-made artifacts. Its more common usage includes all artifacts that aid in the learning process--books or journals, printed programmed instruction, computerized programmed instruction, on-line computer aids to learning and scholarship, closed-circuit lectures on a public address system, educational radio, dial-access audio tape recordings, instructional television--both broadcast and closed-circuit live, as well as tape recorded broadcast, closed-circuit, and dial-access; facsimile transmission of documents by electronic circuits; various automated sorts of information storage and retrieval of written and graphic materials; as well as the many standard audiovisual aids such as wall charts, physical models, transparencies, slides, movies, and displays. The communication channels and nets which make possible widespread use of these technologies also should be included in any consideration of educational technology--

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Note:

This paper is based on three previous papers on general systems theory and its applications to educational processes: (1) Miller, J.G., The Nature of Living Systems, November, 1968; (2) Miller, J.G., The Living Systems Involved in the Educational Process, February, 1969; (3) Miller, J. G. and Rath, G. J., Priority Determination and Resource Allocation by Planning-Programming-Budgeting and Cost-Effectiveness Analysis in Educational Systems, March, 1969.

word-of-mouth transmission in human interaction situations, transmission by courier, by the mails, or by telegraph, teletype, telephone, or television lines, microwave, laser, national, or international communications satellite.

Comparative Evaluation of the Media

We must evaluate, in terms of their comparative benefits, effectiveness, and costs, all these technologies, which have flourished so suddenly in recent years, as available artifacts that can serve as prostheses aiding the learning process.* It is incumbent upon us, with this new-found wealth of resources, not to continue traditional methods of education unless such evaluations of their cost-effectiveness trade-offs demonstrate them to be the most useful and desirable. We must ask what each methodology can contribute to improve education, or cut its costs, or both. Under what circumstances should one technology be employed rather than another? How does each serve to accomplish the long-range purposes or short-range goals of the system? Which contributes most to the individual organism in the educational system, to the group in the classroom, to the school or university as an organization, to the society's educational system or to an international educational system?

*Cf. Miller, J. G. The Nature of Living Systems, pages 36-37.

These instructional technologies should be viewed only as adjuncts to human beings, rather than as substitutes for them. Over the centuries that man has used scrolls and books he has become accustomed to the idea that the book is an aid to the teacher or the professor, usually not a replacement. Apprehension about automation--replacement of the worker by the machine--which exists in many trades and professions today, appears to prevent a general understanding that all the other educational technologies should be used as books are. They are aids to the human beings involved in the educational process. Television or computerized programmed instruction, for instance, should be viewed as means to save the time of students and teachers, freeing the latter for the subtle and vital teaching functions which only human beings can carry out, at least at present. The new technologies may be able to assist in some rote learning functions, or provide more accurate and complete memory, or transmit information more rapidly and to more people than human beings can. This should relieve a load from the educators so that they can then devote themselves to smaller groups of students or individuals, dealing with such matters as those students' motivation to learn; problem-solving--using principles the students have learned in relation to real tasks in their own lives; students' manual dexterities; their attitudes and feelings about what they learn; ethical, moral, and religious issues; philosophical interpretations of the meaning of the knowledge; and other such concerns in which machines will quite possibly never replace human beings. Certainly such gifted

machines are nowhere on the horizon now.

Any educational innovation ideally should be employed, at first, in a situation which permits comparative, controlled, and hopefully continuing cost-effectiveness evaluations. Such evaluation should take into account various sorts of costs: in scarce forms of matter-energy including land, buildings, and hardware; in forms of information, including books, documents, programmed instruction, and other learning materials which are in short supply; in short-range and long-range expenditures of funds available for either capital construction or operations; and in the time of students, teachers, faculty, administrators, and service personnel.* The costs of other related and essential activities must also be calculated, including research on the learning process, procedures for evaluating new technologies, and instruction of teachers and other personnel on how to use the technologies. The fact that several quite different sorts of costs are involved complicates any cost-effectiveness comparison of educational procedures.

Even more difficult is the problem of evaluating educational effectiveness. A number of criteria of educational effectiveness have been suggested by the Subcommittee on Efficiency and Innovation in Education of the Committee for Economic Development:[1]

"Can the proposed technique be effectively employed in the cultivation of an open, inquiring mind? Or does it tend to produce

*See Miller, J. G. The Nature of Living Systems, Op.cit., 45; also Miller, J. G. and Rath, G. J. Op.cit., 21-24.

conformity, dogmatism, and regimentation of thought?

"Is it capable of communicating and facilitating an understanding of complex concepts? Or is its usefulness limited to the management and manipulation of simple ideas?

"Is it capable of cultivating sensitive insight, originality, analytical facility, and creative intellectual skills?

"Can it be employed to induce and deepen artistic and moral sensitivity and appreciation?

"Do the benefits gained justify the costs incurred? Is the initial cost affordable?"

Evaluation of educational benefits or effectiveness is unsophisticated and superficial unless it takes into account considerations like those above. But educational psychology and the other behavioral sciences have supplied us with few effective, reliable, and valid instruments to measure such subtle aspects of human behavior, personality, and social interactions. We are, therefore, in danger of neglecting important variables in the educational systems we are evaluating because we do not have adequate ways to measure them.

Resistance to Change in Educational Methods

Any new instructional technology also should be evaluated in the light of a realistic appraisal of the sociological facts about man's resistance to change. Almost every important innovation in education, or any other field for that matter, has been resisted by

people who are entirely satisfied with the current state of things or who have entrenched interest in maintaining the present state because they would lose certain benefits, comforts, or sources of support if change occurred. When the horseless carriage appeared, the voices in the street cried "Get a horse." When the Wright brothers first flew their plane, the voices proclaimed, "If God had meant man to fly he would have provided him with wings." The modern version of the last complaint is, "If God had meant us to fly without propellors, he would have designed planes with jets."

Comparable attitudes toward new educational inventions have been demonstrated by teachers, professors, and administrators in recent years. Nevitt Sanford has asked:[2]

"How can colleges or universities--essentially conservative institutions--be induced to change? We consider faculty members, note that they have interest vested in things as they are, and suspect that they do not wish to change. We note, too, that the activities of individual teachers are interwoven with those of the institution as a whole and, hence, that even if a teacher wished to change nothing much would happen unless the institution itself was prepared to change. And as for the institution's changing, we are forced to recognize that our colleges and universities are embedded in the larger society, and that they rarely change according to their own plans but only in response to broad social forces.

"Gloom begins to envelop the class, and notes of cynicism are heard. Students who have been planning to go into higher education

with the thought that they might help to improve it begin thinking instead of how they might adapt themselves to the existing systems. Some members of the class point out, hopefully, that innovations do occur in our institutions of higher learning, that today in fact innovation is very much in the air. But others are quick to respond that innovations in established institutions are usually quite superficial, that for important improvements in undergraduate education we have to look to new or rapidly growing institutions, and that even here it is too early to tell whether new models are going to be sustained."

A detailed analysis has been made by Evans of how professors in one university, "Metro University," reacted to an effort to introduce one particular form of innovative educational technology, instructional television.[3] The very real facts of life concerning such faculty resistance are demonstrated. Anyone who does not consider this social phenomenon in his attempts to employ and evaluate educational technology is neglecting a major factor. Strategies for introducing innovations must include plans for countering opposition to them.

The Central Social Issues About Education

Pressing social considerations demand that our concern for instructional technology be more than perfunctory. The rising costs per student of education and the increasing demand for it by all the

people face the society with costs that are causing taxpaper revolts. The dollars required for the traditional modes of elementary, secondary, and higher education make it reasonable to ask whether there is a limit to what the society can afford to pay for it. The quality of much present instruction is devastatingly low by any standards. Many educational systems are not putting out educated students. Or if some education occurs, it is limited, parochial, superficial, and far worse than the best that can be produced. Inequalities of access to education throughout the population are directly related to social class, race, sex, and age differences. In one state--Ohio--out of 100 students who enter grade school, only 14 complete college and fewer than that go on to graduate education. Yet a much higher percentage of the population could profit from advanced education. Furthermore, continuing education in adulthood is much less extensive than it might be. Yet, despite its great costs and its many problems, education is almost universally recognized as a necessity, the primary fashioner of a society's future. Many of today's overwhelmingly difficult national and international problems, it appears, can only be met by more and better education. This fact gives it its high priority among all of man's activities.

The Strengths, Weaknesses, and Costs of Various Instructional Technologies

Table 1 lists the major media of educational technology available today, together with a brief description of the strengths, weaknesses, and costs of each.

Instructional Medium	Can user carry it around?	Can user use it individually at school or college?	Can user use it individually at home?	Can user determine when it is to be used?	Can user control rate of information flow & repeat if not understood?	Can user interact actively with input?	Is individualized "branching" possible?	Senses used	Can signals be sent on electronic network?	Costs (in dollars per user hour)
1. Class lecture	No	No	No	No	Rarely	No	No	Vision & Audition	No	0.15-3
2. Small discussion group	No	No	No	No	Sometimes	Yes	Rarely	Vision & Audition	No	0.50-15
3. Books and journals	Yes	Yes	Yes	Yes, unless another user has it	Yes	No	No	Vision	No	0.05-10
4. Printed programmed instruction	Yes	Yes	Yes	Yes	Yes	No	Yes	Vision	No	0.05-10
5. Computerized programmed instruction	No	Yes	Rarely	Yes, unless number of terminals is limited	Yes	Yes	Yes	Vision & Audition	Yes	2-25
6. On-line computer aids to learning & scholarship	No	Yes	Rarely	Yes, unless number of terminals is limited	Yes	Yes	Yes	Vision	Yes	5-100
7. Closed-circuit lectures on public address system	No	No	No	No	No	No	No	Audition	Yes	0.02-2
8. Educational radio	No	Yes	Yes	No	No	No	No	Audition	Yes	0.01-1
9. Dial-access audio tape recordings	No	Yes	Rarely	Yes	In some systems	Rarely	No	Audition	Yes	0.01-2
10. Broadcast live instructional TV	No	Yes	Sometimes	No	No	No*	No	Vision & Audition	Yes	0.02-10
11. Closed-circuit live instructional TV	No	Yes	No	No	No	No*	No	Vision & Audition	Yes	0.03-3
12. Broadcast tape-recorded instructional TV	No	Yes	Sometimes	No	No*	No*	No	Vision & Audition	Yes	0.01-5
13. Closed-circuit tape recorded instructional TV	No	Yes	No	No	No*	No*	No	Vision & Audition	Yes	0.03-2
14. Dial-access instructional TV	No	Yes	No	Yes, unless number of terminals is limited	Sometimes	Rarely	No	Vision & Audition	Yes	0.50-5
15. Facsimile transmission of documents by electronic circuits	Terminals can be portable & attached to any telephone	Yes	Possibly	Yes, during hrs. sender is able to transmit to user	No	No	No	Vision	Yes	2-15
16. Automated storage & retrieval of written & graphic materials	No	Yes	Rarely	Yes	Yes	Sometimes	Yes	Vision	Yes	2-100
17. Other standard audiovisual aids	Usually	Yes	Often	Yes	Yes	Sometimes	Rarely	Vision & Audition	No	0.05-8

Table 1. Characteristics and Costs of Various Instructional Media

*See text page 17.

The terms which describe the media in the table make clear what they are, with perhaps one or two exceptions. "On-line computer aids to learning and scholarship" refers to such technologies as Project MAC at MIT. An individual user of Project MAC can get access, by a remote terminal on-line to a large time-sharing computer to a wide range of programs that can help him solve mathematical, scientific, and engineering problems, routines for displaying the results of such problem solutions, tests of students' content knowledge in different fields, psychological and behavioral tests, and references or abstracts of articles relevant to many academic tasks. All of these materials are almost instantaneously available for the user to interact with in a "conversational" mode that requires little or no understanding of mathematics or computer programming. The final medium in Table 1, "Other standard audiovisual aids," actually represents several different items such as wall charts, physical models of crystals or parts of the body or machines or houses or mountains, microscope slide projectors, ordinary slide projectors, overhead projectors, moving picture projectors, and so forth. A number of other variants and combinations might be listed, but this table is sufficient to give a panoramic view of the alternative media available to educational systems today.

Many educators are scarcely aware that there are as many alternative forms of educational technology, or at least they have not had direct personal experience with them. One reason for this is that the number of media has risen dramatically because of

technological developments in the last decade or two. When the educators were themselves in school or college they were not yet available.

These technologies are fundamentally products of the Second Industrial Revolution--the information-processing revolution--which burgeoned about 20 years ago, although it began in the last century with the telegraph, the telephone, and radio. The First Industrial Revolution flourished around 1800, being characterized by such major developments as the invention of the cotton gin, the steam boat, the steam engine, the electric motor, electric lights, the automobile, and the airplane. And it continues vigorously up until today with the developments in missiles, space travel, and atomic energy. Of course, the earliest such inventions occurred far back in history or prehistory, with the domestication of animals and the construction of dams and wheeled vehicles. This first revolution produced artifacts which operate as prostheses to living systems at various levels to carry out matter-energy subsystem processes. These machines can carry out these processes faster or more efficiently or with less cost in human energy (although there may be more over-all expenditure of energy) than human beings can themselves.

Now, with the appearance of the computer, with its rapid increase in capacity and sophistication, with the perfection of new communications technologies, and with the general increase in

efficiency and speed and compactness of the machinery which processes information, the second revolution is well underway. We see in operation prostheses to aid living systems in the activities of the entire range of their information-processing subsystems. These include input transducers--microphones, sonar, radar--which can receive signals that cannot be detected by any unaided living system; channels and nets which can transmit information at the speed of light and for great distances; computer aids to learning, to memory, to management decision-making; and output transducers like slide projectors, public address systems, radio, and television that can transmit messages rapidly, accurately, over greater distances, and to more people than can any living system.

Any educational system that is conscientiously intent upon raising the quality and lowering the costs of its functions would do well to undertake cost-benefit or cost-effectiveness analyses, studying the trade-offs among these alternative technologies, attempting to determine which will provide the greatest excellence under what circumstances, and which will be cheapest.

Any such analysis will reveal that it is not enough simply to add these technologies to procedures already in use. This will increase costs and will, in all probability, not permit optimal use of the new methods. Rather both structure and process of the system must usually be altered, often quite fundamentally. People must change their ways. Budgets must be adjusted.

A brief inspection of Table 1 indicates a number of things about the various instructional media available today. First of all, it is apparent that there are a good many of them, the number varying according to how they are classified, but one does not need to extend one's self to list seventeen, as in this table. The first two listed involve only living systems and do not require any artifacts as protheses. For this reason they are separated by a double line from the other media below them. These are the traditional media which have been used for generations, and the choice between them has classically faced educators---whether to use large class lectures or small discussion groups (including individual tutorial sessions).

If one looks across the columns on the chart, it is apparent that no one of the media has exactly the same characeristics as any of the others. This fact makes evaluation of their costs and benefits or effectiveness in different situations essential.

A large body of research on learning, in general psychology and educational psychology, gives us some idea of what constitutes an optimal learning environment. One cannot say that this knowledge is yet definitive, and it clearly differs from individual to individual since each one's genetic characteristics and past experiences result in differences in behavior, personality, and temperament. Nevertheless, one can say with some confidence that aids to learning are most useful if the student can (a) carry them around, for then they are available whenever needed; (b) use them individually rather than having to coordinate his

activities with class groups or other students; (c) use the aids anywhere, both at school or college and at home; (d) determine in terms of his own needs and schedule when to use the materials; (e) control the rate of flow of information inputs and outputs in the learning process, and repeat inputs at will if they are not understood; (f) interact actively with the aids, since active learning is generally recognized as being better than passive; (g) be able to have outputs from him influence the next input coming to him. This "branching" arrangement assures that, if he knows one fact in the progression of the learning process, he is not given special training on it but goes on to the next one and so forth until he comes to a fact which he does not know or a problem which he cannot solve properly, after which he is given special training on that, his time being used for practice only on those facts or problems which he does not understand; (h) receive inputs in more than one sensory modality, since multiple sensory modalities represent multiple channels of input which reinforce each other. Learning aids are more useful if they can be transmitted over electronic networks so that they can reach the student at any place he happens to be, coming rapidly and accurately from any other geographical location. It is also desirable for their costs to be minimal in dollars per user hour, as well as in the time they consume of the student or instructor involved.

None of the media listed in Table 1 is optimal in all these ways. Some are better than others, and some are more appropriate

than others for certain situations or when certain amounts of funds are available to the educational system. These differences among the media make careful analysis of the trade-offs among them mandatory.

For instance, the first column shows that only a few of the media at present are truly portable. The user can carry around with him only books, journals, printed programmed instruction, a number of the standard audiovisual aids such as wall charts, slide and moving picture projectors, and--under certain circumstances, near telephone outlets only--terminals for facsimile transmission of documents. None of the other media, in their present form, are truly portable so far as the average student is concerned. Technical advances may make some of them much more portable in the near future.

The second column in Table 1 shows that students working alone at school or college can profit from most of the media, the exceptions being the class lecture, the small discussion group, and closed-circuit lectures on public address systems. Students can use few of the media at home except books and journals, printed programmed instruction, educational radio, and some others under certain circumstances. Technical improvements in a number of these could render them readily available for home study.

A major constraint upon several of the media, as the fourth column indicates, is that the student must fit his schedule and convenience to that of a group, which limits the most effective use of his time. This is true of class lectures; small discussion groups; closed-circuit lectures on public address systems; educational radio;

and broadcast or closed-circuit, line or tape-recorded instructional television. Indeed, it is probable that any form of radio or television which requires large numbers of students to use the medium simultaneously regiments them undesirably. This may be a major reason why instructional radio and television have not been more effective. The custom of herding students into classes at certain hours is so ingrained in the American educational system that it is hard to break. Many teachers forget or actually do not believe that the optimal learning situation for most students is probably one in which they set their own schedules and study independently.

If the individual student can control the rate of information flows during learning, he is not likely to fall behind in understanding the content or be bored waiting for new concepts to come to him. Many of the media, as the fifth column of Table 1 shows, give the student this sort of control, but some do not. Students rarely exert any influence on the rate of progress of class lectures, which is one of the primary reasons why lectures are far from perfect learning situations. Sometimes students can exert such influence in small discussion groups. If the group is very large, however, some of the students are likely to be too passive or too shy to request a change when the rate of information flow is not optimal for them. Tradition dictates that the experienced, senior person--the teacher--determines information flow rates. Closed-circuit lectures on public address systems, educational radio, television broadcasts, and closed-circuit tape-recorded

instructional television all have these shortcomings as well. So does facsimile transmission of documents by electronic circuits.

Most of the media do not permit the user to interact actively with the input. This is one of the great advantages of the small discussion group and a major point in favor of computerized programmed instruction and of on-line computer aids to learning and scholarship. Under some circumstances, dial-access audio tape recordings make such interaction possible. For instance, a language laboratory tape may present a student with a word or sentence in a foreign language and give him an opportunity to repeat the word or sentence, which is then tape-recorded and later listened to by a teacher who corrects his pronunciation. Similar procedures are possible with dial-access instructional television. Under some circumstances a student or professor can interact with automated data banks for information storage and with some of the standard audiovisual aids. Table 1 shows a number of asterisks in the columns concerned with user control of rate of information flow and user interaction with information input. These asterisks refer to recent technological developments which may in the future be applied to education. A number of these novel forms of television and related technologies which may be of educational value have been described by Licklider, including specialized transmissions to individual users which he calls "narrow casting" and techniques which permit the receiver to respond actively to television transmissions as well as employ television channels to use a variety of other instructional media.[4]

A major potential of programmed instruction and on-line use of computers is individualized instruction. With them a student does not need to rehearse a second time material he already knows. Instead he uses the time for further practice on what he does not know. This can enable the student to save time, or at least allocate it better, in the learning process. Lectures and broadcasts do not usually have such a potential, although on occasion very small discussion groups or individual tutorial sessions do. The programming technique whereby each student is given practice only on what he does not know is called "branching." Such branching is less personalized, flexible and sophisticated in the best printed programmed instruction than in the best computerized programmed instruction and on-line computer aids to learning and scholarship. Various automated storage and retrieval technologies also permit a close tailoring of the process to the needs of the individual user.

As the eighth column of Table 1 indicates, the face-to-face human situation in classes and small discussion groups has the great advantage of using both vision and audition, as well as some of the other sensory modalities on occasion. Books, journals, printed programmed instruction, on-line computer aids to learning and scholarship, closed-circuit lectures on public address systems, educational radio, dial-access audio tape-recordings, facsimile transmission of documents by electronic circuits, automated storage and retrieval of written and graphic materials, and some standard audiovisual aids do not use both sensory modalities. Other standard audiovisual aids do,

such as sound moving pictures. So do all the different forms of television. This is one reason why television is probably superior in conveying a sense of intimate and direct human relationships to books, computer terminals, radio, and other solely auditory presentations.

If educational materials can be transmitted over electronic channels and networks, they can, in principle, be initiated at any geographical point and be used at any other point. This facilitates diffusion of knowledge and makes possible democracy of access to educational information. The face-to-face relationships of class lectures and small discussion groups do not have this potential, nor do books, journals, printed programmed instruction, or the standard audiovisual aids. As the next-to-last column of Table 1 shows, all the other media do, since they are electronic. In the last few years educators have, thus, been presented with a challenge: How can the new network media be most profitably and creatively used in future educational activities?

Now we come to the question of costs. The last column of Table 1 lists only dollar costs in various sorts of matter-energy and information, although, of course, costs in student, teacher, administrative, and other staff time are also important. The dollar estimates include both operating funds and an appropriate portion of capital construction funds. For all of the media there is a wide range in costs, because it is extraordinarily difficult to make even rough cost estimates with our present knowledge of the media. This is an important area for future research and investigation. Many variables influence the dollar cost per user hour of these different media. Among these are: the

number of students using the medium at a given location and at a given time; the ratio between the number of students and the number of instructors; the amount of hardware employed in the particular system under study; the number of hours the hardware is used on the average by each student; the original costs of the hardware (which over the years recently have been rapidly decreasing); whether the hardware is bought in large quantities; and whether the software needs to be written for the local system or has already been prepared for another system.

All the costs listed in the last column of Table 1, because of the fluctuation of these many factors, have a range such that the highest cost is one to four magnitudes larger than the lowest. A few general observations can be made: (a) Large class lectures are less expensive than small discussion groups. (b) Even though none of the electronic media have all the advantages of direct human contact, some of them appear to be, at least potentially, as cheap or cheaper than traditional methods of teaching by direct human contact. (c) Books, journals, and other printed materials are, in general, cheaper than most of the electronic technologies, though this is not necessarily true. (d) Electronic technologies involving both vision and audition are somewhat more expensive than those that involve audition alone. (e) Those media which involve on-line access to computers are, in general, significantly more expensive than the other media, at least at their present stage of development.

The Effectiveness and Costs of Instructional Television

Though in most educational systems the use of instructional

television is desultory and its potential is not realized, there are some exceptions. Among these are Chicago's Television College, broadcasting entire junior college course sequences, a closed-circuit television system which centers in Hagerstown, Maryland, and the extensive televised on-campus courses provided by Pennsylvania State University at State College, Pennsylvania. As Murphy and Gross note, good instructional television can create a powerful learning environment:[5]

"If TV has one quality that is peculiar to the medium, it is its immediacy--its ability to transmit experience instantaneously. 'Creative TV,' says Patricia Swenson, supervisor of radio-TV for the schools of Portland, Oregon, 'is vivid, human, informal, warm, compelling. There can be, strange as it may seem, an astonishingly intimate relationship between TV teacher and child.' The Portland schools have been proceeding slowly in their use of television, aiming at quality rather than quantity, but the unpretentious series Dr. Swenson produced, Let's Explore Science, has gained disciples all around the country. Throughout the series, the writer-tele-teacher, Peter Taylor, uses the camera to sweep youngsters along as colleagues in his inquiries into such things as the pendulum, simple balances, rolling balls, and household liquids. The programs evoke rather than overwhelm the child's curiousity about the everyday world.

"Another good example of ITV's breaking out of the old molds is the series of brief, weekly programs called Roundabout, produced by the Washington, D. C., ETV station, WETA. Inspired by the Head Start idea, and produced by Dr. Rose Mukerji of Brooklyn College, these programs--probably the first of their kind--are designed, with

imagination and skill, to appeal to preschoolers living in urban slums. Now being broadcast for the second time in the Washington area, the taped series has been made available for national distribution and is currently being shown in New York City. Most of the fifty-two programs, which are set in familiar neighborhood backgrounds, make use of Negro children and a young Negro male who is neither teacher nor actor but rather an older brother. They deal with a splendid variety of simple but eye-opening topics; barbers and bus drivers, art (the use of clay and paint), hinges, jobs, families, the ways of turtles. The most controversial program, called Living or Dead? inspects a dead parakeet, compares a live goldfish with a dead one, and relates the concept of life and death to human beings, in a very matter-of-fact way.

"Less ambitious, but also direct and lively, is a news program that is put on every morning by children in a Larchmont, New York, elementary school, and that goes by closed circuit to every classroom. Children from the fourth, fifth, and sixth grades--with four teachers as advisors--write, edit, cast, and produce the show, which includes news, weather, editorials.

"Closely allied with immediacy is intimacy--the fact that TV can bring one face to face with the action in a peculiarly close relationship. For example, the televised scientific demonstration makes it possible for a great many students to see with clarity on the screen what only a handful could see with their own eyes. As an experienced surgeon performs an intricate operation in an amphitheater before hundreds of students, each of them has an over-the-shoulder

view, thanks to television. An extension of this idea is postgraduate education by TV. UCLA's series for doctors, for instance, is broadcast weekly forty weeks out of the year from Los Angeles's new ETV station, KCET (scrambled, to spare the squeamish layman), and goes to eighty-one hospitals and an estimated audience of 3,000 to 4,000 doctors. An incidental footnote which raises more questions than it answers about the medium's peculiarities: KCET finds that doctors experience the same immediacy with taped programs as with those that are live. Films, no; tapes, yes."

What is the validity of television as an instructional tool? The answer is that it works, as Chu and Schramm said in 1967 after a careful analysis of the evidence:[6]

"We have recently reviewed, up to 1966, 207 published studies in which television teaching has been compared with conventional teaching. Of the 421 separate comparisons made in these studies, 308 showed no significant differences, 63 showed television instruction to be superior, and 50 found conventional instruction better.

"Therefore, all these summaries show that in the great majority of comparative studies, there is no significant difference between learning from television and learning from conventional teaching; and that where there is a significant difference, it is a bit more likely to be in favor of television than of conventional instruction."

A study on the costs of some of the new educational technologies carried out for the Committee for Economic Development by Booz, Allen,

and Hamilton, Inc. recognized that there are many cost variables in costs in the production of instructional materials and their dissemination. They recognized also that widespread use of the media would result in reorganization of the processes going on in the systems that used them, which hopefully would upgrade the quality of the instruction.

Making certain assumptions about the nature of a educational system that uses television, they calculated that the hardware costs for a 24-classroom school would be about $30,000 and that the costs for supplying a school system of 100,000 with one hour of television programming a day for each student would range from $800,000 to $4,600,000 a year. This would be between 4 and 24 cents per user hour. At this rate the annual cost for television in our national elementary and secondary school population would range from $265 million to $1.5 billion. There would be certain savings in scale if program materials were prepared jointly and if there were control administration of a massive national program of instructional television. Public school expenditures for the United States in the 1967-68 school year were estimated at $30 billion, including operating expenses and capital expenditures. Therefore, the study concluded that a television bill ranging up to $1.5 billion could be accommodated, and it would certainly bring about some offsetting savings.

The Effectiveness and Costs of Computer-Aided Instruction

In a survey questionnaire sent to 2503 superintendents of

school systems in 1968, which elicited 746 replies, the respondents rated promising educational innovations in the following order: first, individualized instruction; second, vocational and technical training; third, in-service training; and fourth, instructional television. Computer-assisted instruction was much less popular, being second or third from the end. There is no question that the use of instructional television is better understood and more appreciated by education today than is computer-aided instruction.

Nevertheless, computer-aided instruction has real strengths, as pointed out by Mary Gardiner Jones, a commissioner of the Federal Trade Commission:[7]

"The introduction into our educational system of the computer and of the wide variety of associated electronic and mechanical teaching devices, together with entirely new programmed instructional material, presents us for the first time with unique opportunities to deal effectively with many of our educational problems. Use of programmed instructional materials will enable schools to offer a type of individualized instruction geared to the backgrounds and experience of each student. The student can proceed at his own pace and through the branching ability of the computer, the teaching materials can be tailored to the particular difficulty being encountered by individual students. To a certain extent, the student's manipulation of his own computer console can compel him to participate more directly in the educational process and presumably will not enable him to day-dream undetected through entire classes. [Also, as he learns he can create a complete computer

record of how far and how fast he went in the process. This record can be substituted for examinations.]

"At the same time, computers and other mechanical teaching devices can consistently exercise a degree of patience, encouragement and affirmative support for the struggling learners which no teacher has either the time or the saintliness to display at every moment of the day and on every day of the week. [As long as universities have 20-to-1 ratios of full-time-equivalent students to faculty, no faculty member will ever be able to give as much undivided attention to the 20 full-time equivalent students for whom he is responsible as a computer potentially can.]

"With respect to the sheer acquisition of information and the basic technique of learning, these devices can take over much of the routine drill aspects of teaching and thus free the teacher for those aspects of education which he or she is uniquely capable of doing, namely, to question, to imagine, to invent, to appreciate, to act as a model, a guide, a counselor and fellow-searcher after truth, after values and after meaning and understanding."

Writing on the basis of several years' experience in computer-assisted instruction, Atkinson has reported results from the first year of an experiment using computerized programmed instruction to teach reading to first grade students.[8] He and his associates compared an experimental group with a matched control group. Each group was made up of about 50 first grade students from "culturally

disadvantaged" homes, with I.Q.'s averaging 89. The experimental group received their instruction by computer-aided instruction and the control group by traditional classroom teaching. The fastest student taking computer-aided instruction completed over 4,000 more "central" problems during his whole course of study than the slowest student. This indicates how individualized computer-aided instruction can be. Both groups were tested with conventional instruments before the project began and again near the end of the school year. The two groups were not significantly different at the beginning of the year, but at the end the group receiving computer-aided instruction was significantly better on all of the following posttests: California Achievement Test, Vocabulary Subtest and Total Score; Hartley Reading Test, Form Class Subtest, Vocabulary Subtest, Phonetic Discrimination Subtest, Nonsense Word Pronunciation Test, Word Pronunciation Test, Nonsense Word Recognition Test, and Word Recognition Test. There was no significant difference between the two groups on the California Achievement Test Comprehension Subtest. These findings as a whole constitute an impressive indication of the potential effectiveness of computer-aided instruction.

There is no clear agreement about the present or probable future costs of computerized programmed instruction.

Atkinson and his colleague, Suppes, at Stanford University have developed computerized materials for learning language skills for grades 4, 5, and 6. They calculate that in a school with 100 terminals which maintained an active program for at least two years, the total

cost of using these materials would be about $1.80 per user hour, including all expenses such as terminal rental and royalties. To develop 200 40-minute instructional units cost them about $60,000, or $300 a unit.[9]

Preparation of such instructional units, according to Bacon at the San Jose laboratories of IBM, costs between $500 and $3,000 per student hour, varying greatly with the media, amount of branching, and types of materials.[10] The following uses of computer-aided instruction he believes are within practical cost ranges today: (a) For the early grades, simple drills coupled with diagnostic tests showing weaknesses, in such fields as arithmetic and reading. (b) Either before college or earlier, remedial mathematics, grammar, and other subjects. (c) In advanced professional fields, medical diagnosis, business games, computer-aided design, technical simulation, simulation of organizations, and logistic problems.

A study by Kopstein and Seidel compared the costs of traditional classroom instruction with computer-aided instruction in public elementary and secondary schools, higher education, and military technical training.[11] They calculated that in elementary and secondary education, costs of traditional instruction will average about 38 cents per student hour in 1971 and rise to 42 cents by 1974-75. For higher education the cost is higher, rising from between 37 and 46 cents per student hour in 1949-50 to between 82 cents and $1.02 per student hour in 1963-64, the last date for reliable data. In military and technical training they believe that $1.80 may be about the average cost per

student hour. Making a certain number of assumptions, they calculated that the total costs of computer-aided instruction at present amount to $3.73 per student hour and concluded that unless this medium can be shown to be at least ten times more effective than traditionally administered instruction, a replacement does not now seem to be justified. They believe, however, that with further developments which seem likely to occur in the field of computer-assisted instruction, a forecast of costs of 11 cents per student hour for computer-assisted instruction seemed probable in a few years.

According to Zinn, costs for computer-aided instruction are reported by various workers as ranging between $2 and $15 per user hour, although one project claims it has achieved a cost of only 27 cents per user hour at consoles which include a keyboard, graphic display, and image projector.[12]

The Booz, Allen, and Hamilton group which studied instructional television (see page 23), concluded that the costs of computer-assisted instruction are relatively much higher. They calculated that for a 100,000 student school system the annual rental cost for present hardware needed for one student hour a day of drill-and-practice computer-aided instruction would be $20 million; $6 million would be required for other services; and about $765,000 would be consumed annually for software, making a total of about $27 million for a 100,000 student system, or about $1.35 per user hour. If the more complex tutorial mode of operating computer-aided instruction were employed, they calculated that one hour of software would cost about $30,000 to

produce. (This cost is much higher than the cost of some such software now being produced.) For on hour of such instruction daily in a school system of 100,000, the annual software cost would, therefore, be about $5 million, hardware rental about $50 million, and other services about $17 million, for a total of about $72 million, or about $3.70 per user hour. It seemed to this group that at an annual cost in this range the large-scale use of computer-assisted instruction is at present too expensive when possible benefits are considered, but they believed that probably such costs will come down in the not-too-distant future and recommended research to decrease them.

Examples of Introduction of New Technologies into Various Levels of Educational Systems

When instructional technologies are introduced into educational systems, one or more prostheses are made available to aid the human beings in the system. This may or may not relieve them of processes they are carrying out or reorganize those processes. It is desirable insofar as possible to introduce these technologies into the system only after cost-effectiveness analyses are made and reviewed. Sometimes these can be quite precise and quantitative, particularly if management information systems exist in the educational system which provide data relevant to these decisions. Under other circumstances, only a rough calculation of costs and benefits or effectiveness is possible, either because the relevant data are not available or because so many variables are involved that it is not feasible to measure them or to collect information about them. Below is a series of fictional examples of how such an approach might be

taken to decisions on whether to use new instructional media in educational systems at various levels:

1. A school.

An elementary school which has a large number of underprivileged children concludes that it may be desirable to use carrels in its first grade classrooms. Its purposes in using such carrels include: (a) To socialize children to the learning environment of the school by giving them periods when they are isolated from most extraneous information inputs and can carry out independent learning experiences. (b) To prepare the children for independent study in automated carrels which the school expects to introduce within two years at grades 3 and above.

Carrels are booths which constitute an interface between the student and some artifact from which he can receive information inputs. They can be classified into two general types: general space carrels, an enclosure with a door by which the student may isolate himself from the environment for periods of self-initiated study; and multimedium carrels, which include in the booth a typewriter on-line to a computer terminal, a source of auditory inputs, a screen capable of showing letters or figures, graphic material, or television pictures, and a light pencil with which the student can respond to inputs by pointing to any part of the screen, which signals the computer where he is pointing.

Inside the general space carrel the student could use a book, a television set, a projector showing slides or movies on a

little screen, or a record player with headset. In terms of effectiveness in learning how to carry out tasks in multimedium carrels, such a carrel would probably be best for the first grade, even though the students could not yet type, although they might push a few keys to send a limited repertoire of signals to the computer. They easily could look at the screen, use the light pencil, and listen to the auditory inputs. On the other hand, both the general space carrel and the multimedium carrel would accustom the student to a period of independent activity each day separated from the other students and inputs from them. In this latter learning experience they would probably be equally effective, and in the first grade this type of effectiveness would probably be more important than the other. The difference in cost of the two sorts of carrels is great. In calculating the costs of the carrels, the following considerations must be included: The purchase cost of each carrel and the rate at which it must be depreciated. The number of carrels for each classroom of 30 students; this might be either five carrels (each student spending one hour out of the six hours in the school day in a carrel) or ten carrels (which would permit each student to spend two hours a day.) Maintenance costs of the carrels. Costs of supplies and equipment used in the carrels. Maintenance of equipment used in the carrels. Payment for extra time of teacher aides for using the carrels and supervising students in them. Even with extra equipment in the general space carrel, the average cost per student hour in each carrel if there are five carrels per room would be 25 cents

in the general space carrel but at least $1.25 per hour in the multimedium carrel. In a school that has 300 first grade students the difference in cost would be $7,500 a year for the general space carrels versus $37,500 a year for the multimedium carrels. The cost of the latter would be far too great for the benefits obtained, so the former must almost certainly be chosen. This is particularly true since adding these carrels would relieve no teacher time. It would simply improve the quality of education of the underpriviledged children who had not been used to solitary activity before coming to school. By the time the pupils got to third grade, the amount of individualized instruction that could be obtained from a multimedium carrel and the saving in teacher time might well be enough to justify the relatively high expenditure for such carrels.

2. A school system.

This particular school system has already installed a closed-circuit television system connecting all of its high schools. It now is trying to decide whether or not to buy video tape-recording equipment. The purposes and benefits which it expects such equipment to achieve are as follows: (a) To be able to develop special instructional programs that can be reused at various times of the day or week for different sections of the same class as well as in subsequent years. (b) To be able to use in the training of teachers video recordings of student-teachers operating in classes and of experienced teachers operating in classes. (c) To be able to produce for commercial television special public service programs about the school system. (d) To increase the student-teacher ratio in some courses by having classes

given by video tape lectures rather than by live teachers.

Among the alternative procedures to be considered are live teaching in traditional classrooms and moving pictures.

The costs of this proposed innovation include the money expended to buy the new equipment; teacher time used in learning to use the new medium and in taping materials; as well as lowered morale of those in the teaching staff who oppose the new procedure.

An analysis of cost-effectiveness ratios relevant to the decision to introduce the tape recorder is shown in Table 2.*

For the video tape-recording system, we assume that the probability (P_i) of it being accepted is about 50-50 (.5). This is determined by the school system management that makes the decisions whether to purchase the equipment, usually based primarily on attitudes of the teachers. Compared to movies or live teaching, its utility (U_i) may be rated relatively high (10) because of its convenience to the teachers. Its cost will be $10,000, and so C_i is 10,000. This is the cost-effectiveness measure for the teacher and we will add to it a cost-effectiveness measure to the students based on the same formula, as follows: To the students it is not especially helpful and there is no great joy in seeing black and white television (2). The price is $4,000 for the year, which is the cost

*This presentation is based on the mathematical approach to the setting of priorities outlined in our previous paper in this series: Miller, J. G. & Rath, G. J. Priority Determination and Resource Allocation by Planning-Programming-Budgeting and Cost-Effectiveness Analysis in Educational Systems. March, 1969.

Faculty | Students

$$E = \sum \frac{P_i \times U_i}{C_i} \qquad E_i = \frac{P_{fac,i} \times U_{fac,i}}{C_i} + \frac{P_{stu+i} \times U_{stu+i}}{C_i}$$

$$E_{vtr} = \frac{.5 \times 10}{4,000} + \frac{.5 \times 2}{4,000} = 15:10,000$$

$$E_{live} = \frac{.9 \times 50}{10,000} + \frac{.9 \times 10}{10,000} = 13.5:10,000$$

$$E_{film} = \frac{.1 \times 5}{2,000} + \frac{.1 \times 20}{2,000} = 12.5:10,000$$

E_{vtr} = effectiveness of video tape recorder

E_{live} = effectiveness of live teaching in traditional classrooms

E_{film} = effectiveness of moving pictures

Table 2.

Cost-Effectiveness Evaluation About Use of Tape Recorder

of the machine plus some technician time to operate it. It is an identical cost for teachers and students because it is the same equipment for both of them. The live performance on the television has a probability of being effective which is much higher (.9). The cost of $10,000 is the same in both cases, and high, because the medium requires having one or more live persons available. It is highly acceptable to teachers because they do less work than if they prepare television tapes (50). The students like to participate in a live professional teaching performance, so their rating is 10.

The moving picture has the lowest probability of success (.1) because it is difficult to find films that will do the job. On the other hand, films, when they are available, are cheap ($2,000). For the teachers the film has a low utility because they have to choose the film, load the projector, and show the picture. The students prefer films over black and white television because they like the color and the high quality of production; there is generally much better entertainment value in films than in homemade television broadcasts (20). Finally, looking at the cost-effectiveness ratios the decision is to invest in the videotape recorder.

Obviously the alternatives are close enough that other factors might decide. If a grant were offered to create a film library, so that the operating budget did not need to support it, that would swing the decision to moving pictures. On the other hand, if some of the best teachers enjoyed live teaching so much that they would leave if

taped television or moving pictures were used, the wisest decision might be to raise the teachers' salaries and forget the video tape-recorder.*

3. A college.

At a state supported urban college a new president, much more aware of the implications for higher education of the urban crisis than his predecessor had been, determined to increase the percentage of the students living in urban central city slum areas from 2 to 20 percent over a three year period. Then the admissions staff began to interview the high school graduates from such areas. They found that their preparatory education was seriously lacking, so that they needed individualized remedial education. There was no subsidy available for such remedial education, however, so the college was under stringent financial necessity to carry out this individualized training as inexpensively as possible. They discovered that computer-aided remedial instruction programs in mathematical skills and language utilization were available without cost, so they made an effort to determine whether computer-aided instruction was the most feasible way to give this remedial education. Alternative plans were to hire individual tutors, to lighten the ordinary teaching load of volunteer faculty members so that they can tutor, or to pay junior and senior students to give this remedial education to incoming freshmen.

*The last two sections were adapted from materials provided by G. J. Rath, Professor of Industrial Engineering and Management Sciences, The Technological Institute, Northwestern University.

The college's purposes in instituting this new program were as follows: (a) To increase the probability that urban slum students in need of remedial education, would be able to complete their freshmen year and continue into the sophomore year and work toward a bachelor's degree. (b) To improve the basic mathematical and linguistic skills of these students. (c) To raise the freshmen grades of these students.

Once it was determined that the computer-aided instruction programs of remedial education could be obtained free of charge from another university, the costs were calculated of giving each student in need of remedial training three hours a day of instruction in computer-aided instruction. This involved obtaining an IBM 1500 Computer with 30 terminals. The cost with this configuration for 30 students was $22 an hour. On the other hand, if the configuration was enlarged to 120 terminals and used in four 3-hour shifts each day, the cost was reduced to $8.82 per student hour. Furthermore, pretests indicated that the learning rate of students with this form of individualized instruction was about 20 percent faster than with human tutors. At the end of the first year it was found that the course grades of students taught with computer-aided instruction were significantly better than those taught by traditional tutoring methods.

With student tutors paid at the rate of $1,000 a year, each of whom tutored three students ten hours a week, the cost was $1.80 a student hour, including administrative costs. With volunteer

faculty who received reduced loads (the loads in half of the departments having to be made up by teaching assistants that were hired especially for the purpose), the costs were $2.88 per student hour. It was unclear from any evidence whether the students learned better with the student tutors or with the faculty tutors.

The administration finally made the decision that the advantages of computer-aided instruction were great enough to justify its extra cost even though it represented a severe drain on the total college budget. This decision was made after it was learned that 300 students in need of remedial training would be in the freshman class in the next year. Unless this number could have been recruited, the computer-assisted instruction costs would have been exorbitant. One loss to the college was that there was not so much employment for junior and senior students who needed jobs as tutors. On the other hand, an advantage to the college was that the faculty were not taken away from their regular teaching activities, which represented its major strength.

4. A university.

A private university over a period of 15 years had grown from 4,000 to 15,000 students. Most of the buildings used by the College of Arts and Sciences had been designed before this period of rapid growth. They had been built an average of 44 years before. A few large classrooms in the buildings could accomodate a maximum of 80 students but most of them could accomodate no more than 40 students. Small classes had been universal at the university until

ten years before. It now became clear to the administration that if tuition were to be kept low enough that most of their applicants could afford it, they would need to raise the student-faculty ratio and have larger classes. Two alternatives were considered: (a) To build a new building including two classrooms capable of holding up to 500 students each, at a total cost of $2,500,000, and (b) To install closed-circuit television in all the buildings of the College of Arts and Sciences.

The goals which the college's president wished to accomplish were: (a) To increase the student-faculty ratio from 20 to 1 to 28 to 1, in order to keep tuitions within range. (b) To maintain or improve the quality of instruction as reflected by students' performance on various tests. (c) To minimize expenditures for capital construction and equipment.

The cost of the new building had been set at $2,500,000. Of this $1 million was available in cash and the rest could be obtained from long-term loans. The building could be depreciated over at least 50 years. Maintenance costs for the building would be $9,000 a year. With interest charges included, the cost per year for the building would be $88,000.

A closed-circuit television system for all the buildings in the College of Arts and Sciences would have the following costs: Laying of television cables between all the buildings, $83,000; interconnecting all rooms with television cables and installing black-and-white television monitors in each room, $680,000; television studio, tape banks, and tape recorders, $128,000. Total $891,000.

This cost could reasonably be depreciated over at least a 20-year period, so the cost per year would be $45,000.

Research on live as compared to televised instruction suggests that students like televised instruction less but that it is not less effective. Use of televised instruction would make possible an average student-faculty ratio of 35 to 1, so that if the college were to achieve an over-all 28 to 1 ratio, one quarter of the faculty time could be devoted to small group discussions and individual conferences as a result of savings by using closed-circuit television. This would also be true if large classrooms were used.

For a time it appeared that the nature of gifts and grants available meant that the administration could obtain capital funds but not equipment funds. Finally an agreement was reached, however, whereby the money could be used for either purpose. The management decision was then made to install the closed-circuit television. At the same time that this decision was made, the hiring rate of all departments in the college was slowed down over a four-year period so that gradually over that time the college would increase from its former 20-to-1 to the desired 28-to-1 student-faculty ratio. Costs were cut significantly and there was no clear indication that the effectiveness of education suffered. It might even have been improved. At the very least, tuition rates were kept down in an inflationary period.

5. A state system of higher education.

Over the decade between 1955 and 1965 the number of state-supported colleges and universities in one state had increased from 5 to 13, and the number of students had more than doubled. The state budget for higher education had gone up from $125,000,000 a year to $280,000,000 a year. The percentage of the total statewide higher education budget devoted to libraries had crept up from 3 percent in 1955 to 5 1/2 percent, and in three of the new universities it was up to 7 percent. Despite this four of the campuses in the state had libraries of less than 250,000 books and only one had a collection of more than 1,500,000 volumes. There was a very unequal distribution of books among the various campuses of the state. This inequity would continue for many years, if it could ever be corrected, even though the percentage of funds going to libraries rose to an unacceptable level.

Consideration was given to continuing previous policies, gradually increasing the percentage of the statewide higher education budget devoted to libraries up to 8 percent. But this policy would mean that for the next decade 8 of the 13 campuses in the state were predestined to have collections inadequate for extensive graduate work. An alternative was to establish a single statewide computerized union catalog and a network for facsimile transmission of documents from one campus to another.

The purposes of the state Board of Regents were as follows: (a) To equalize access to scholarly information on all campuses of the state. (b) To make available to every campus a library of the

highest quality capable of supporting both undergraduate and graduate education. (c) To spend no more than 6 percent of the total higher education budget in any one year for libraries and library services.

It was expected that the statewide budget for higher education would increase an average $20,000,000 a year for the next 10 years so that this 6 percent of the budget that was spent for libraries, over the next ten years the library services budget for the state system would average $22,800,000 a year.

This amount of money would purchase and catalog 2,280,000 books a year by traditional methods at an average cost of $10 a book. These purchases divided around the 13 campuses would mean that at the end of a decade the average campus would still have only slightly more than 500,000 books and journals.

An alternate plan was to store certain classes of books in each library based on a joint acquisition policy. Each campus would have a core collection of 100,000 volumes of standard works and an additional 50,000 volumes of microfilmed journals and books. Calculations indicated that such a core collection would meet 83 percent of the demand on the typical campus. In addition each campus would keep the other books and journals it already had but transmit facsimiles of them statewide on demand. It was calculated that, with these procedures, on the average 7 percent of the demand would not be met locally. Since 7 percent of the demand represented an average of 183,000 volumes a year, efforts were made to calculate how much

it would cost to transmit copies of these documents over a facsimile network. Two percent could be saved because 3 of the 13 universities were close enough to each other so that a courier could be used to carry books or journals from one to another. Including administrative costs for this system it was found the average transmission costs for a book would be $13, including an average royalty of $1 per book paid by agreement to the publisher. This included long-line rental charges and local terminal charges of $12,000 a year per campus. On the average a volume could be available by long distance xerography in an hour and a half from any place in the state. The total of 175,340 (183,000--2 percent of 183,000 or 7,660) volumes requested times $13 per book would cost $2,279,420 annually to transmit. This plus the cost of the local collections added up to $21,400,220 annually. This total program meant that statewide availability to a library totalling nearly 4,000,000 volumes could be provided within 10 years, and although browsing of these volumes was not immediately possible, access to every volume could be obtained within an hour and a half anywhere in the state, except those where delivery was by courier, which took a maximum of four hours. The state thus could have a very large and diversified collection, since no more than one copy of any volume needed to be purchased. When there was a demand for a second copy a facsimile could be made. This alternative library plan was accepted by the state since it was clearly more efficient than the first and

no more expensive.

The fact that browsing was not at first possible could spur scientists in the state, in cooperation with others throughout the world, to carry out research on basic linguistics so that ultimately digital storage in computer memories of the complete text of books might be possible, making feasible computerized searching of the contents of the texts over networks.

6. A national educational system.

Promising alternatives to our country's traditional methods of education should be reviewed at the national level. If there is no democracy of access to information in any state, it is obvious that this is even more true nationwide. If it is desirable to share library resources by a network throughout a state, it is obviously even more desirable and profitable to share the resources of book libraries and stores of many other media nationwide. This sharing of resources, if properly arranged, can raise the quality of educational information services and cut their costs. It therefore seems desirable and feasible to establish national networks for knowledge, or educational networks, as described in the book EDUNET.[13] A consortium of universities throughout the country working together can share the resources of all the electronic media listed in Table 1.

The costs and effectiveness of such a national multimedium network are hard to evaluate. Many variables must be considered. The amounts of time and money required to put such a system in operation

are very large, but its potential benefits are probably even greater. If a serious effort is to be made to establish such a network, undoubtedly cost-effectiveness analyses must be carried out. All we can do here is to state the obvious need for serious consideration of this multimedium adjunct to university education. For optimal service such networks probably should be interdisciplinary; include all useful information-processing media; provide similar services to all parts of the country; provide on-demand access of all sorts of information to the user; and be operated as a nonprofit system with appropriate collaboration between colleges, universities, and schools as well as other nonprofit institutions in education, industry, and the government.

7. Incernational education.

From an engineer's point of view there is no reason why what can be done for education by the use of the new technologies on a national basis cannot be done internationally. When other countries become involved, ' 'ever, the problems of organization and technical cooperation become vast, just as the possible benefits become tremendous. Educational satellites and new laser transmission systems are under study which may enable us to transmit information in very large quantities at rapid rates throughout the world. This can be done either over electronic networks, or by shipping electronic or other forms of memory through the mails, by ship, or by plane. For example, computer-aided instruction terminals with programs stored on magnetic tapes in cassettes and with self-contained power systems could be sent to any part of the

world. If they were mass produced they could be reasonably inexpensive Problems of translation and embedding of such an educational system in the local culture would be serious, but could be solved. This is perhaps the only way that some of the developing nations which have few adequately trained teachers to educate the younger generation could afford to take a big leap forward to catch up with the Twentieth Century as it is known in the more developed lands. At the very least an intensive review of the role of the new media in international education is indicated.

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